THE INSTITUTION OF PRODUCTION ENGINEERS JOURNAL

THE INSTITUTION OF

PRODUCTION ENGINEERS JOURNAL

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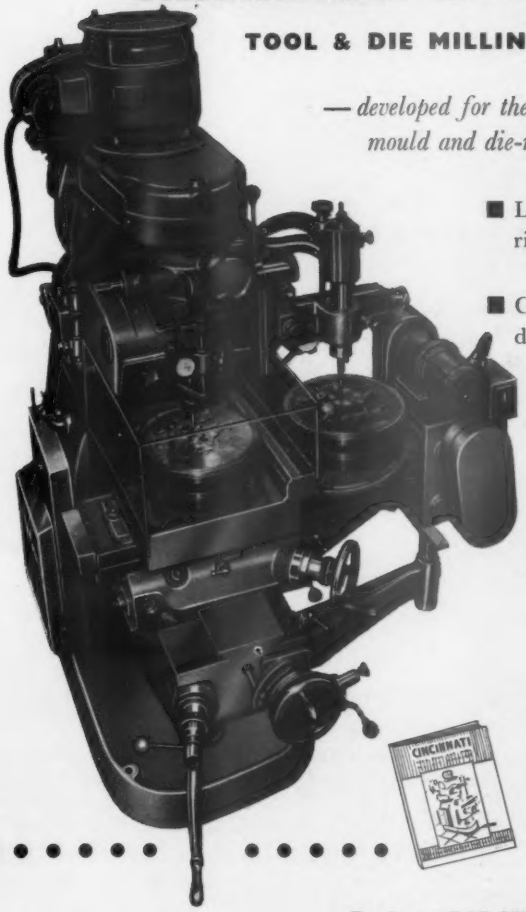

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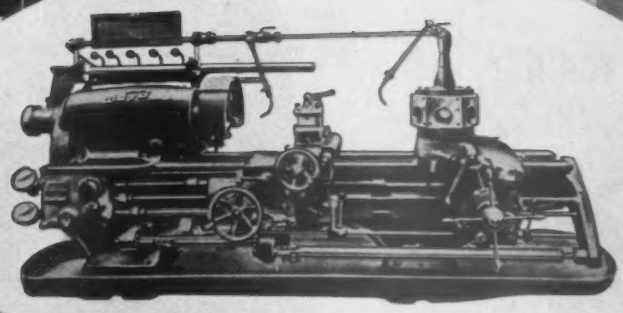

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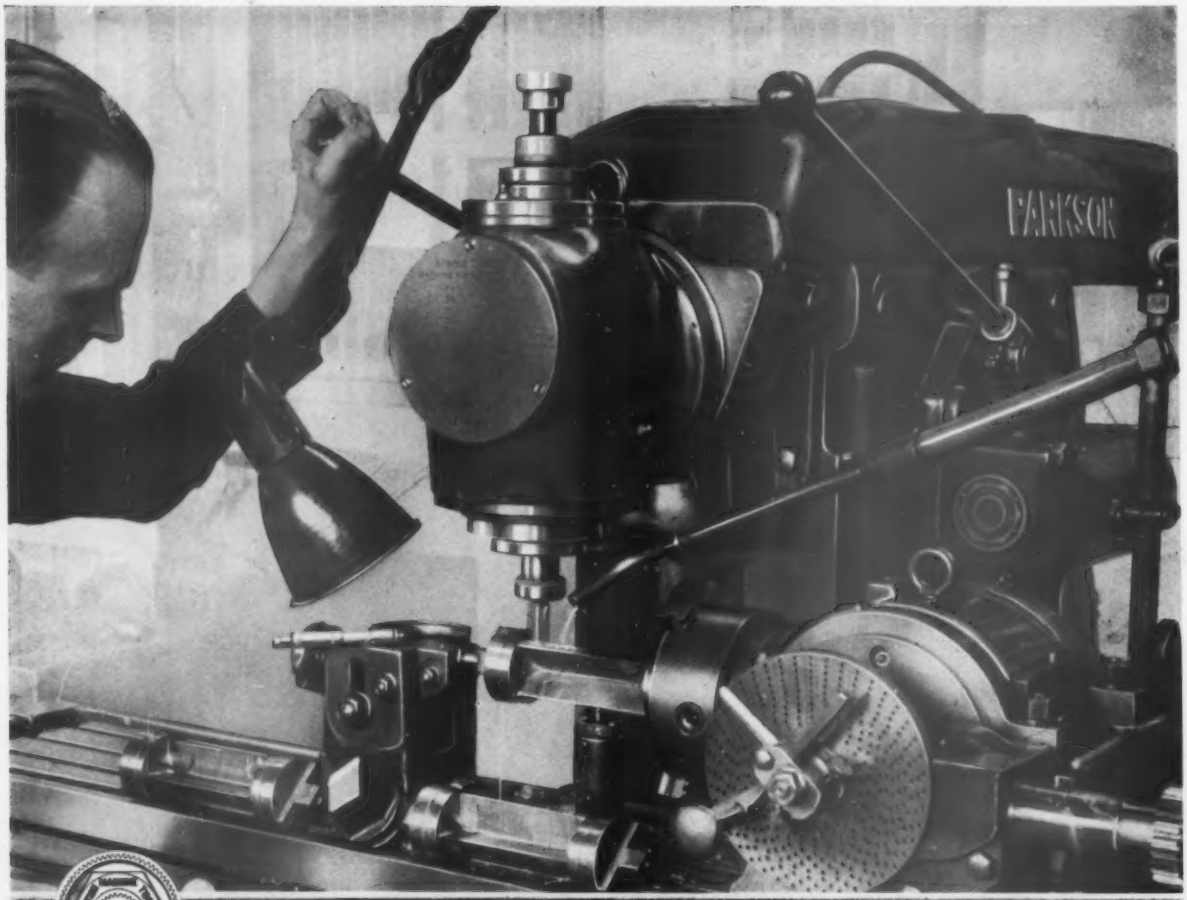

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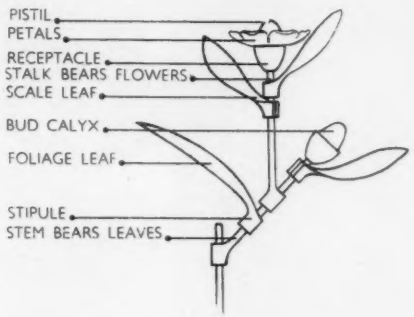
Designer's Diary No. 9

Reprints of this announcement will be sent on request.

For the second year in succession, A. H. Woodfull, M.S.I.A., Chief Designer of the B.I.P. Product Design Unit, has won the first prize in the annual competition for plastics design sponsored by the Worshipful Company of Horners. This constructional toy was his winning entry in the 1952 competition.



The Product. Although much has been done to provide children with constructional toys which stimulate imagination and develop manual skill, there is still considerable scope for toys with a direct educational value. The toy illustrated aims to foster an interest in botany, since a child needs at least to have an elementary understanding of natural plant growth before being able correctly to assemble the components.

The Design. The split heels of the standard leaf and stalk are a push-fit upon each other. The angles are arranged to provide an infinitely variable arrangement of the finished plant, overcoming any possibility of geometrical appearance.

The pot forms a natural pack for the components. The lid has a raised square platform with a pattern of blind holes which forms the foundation for plant building. The lid is secured by a cam-type locking device, instead of the more conventional threads, so that it can be easily opened and closed by quite a young child; this arrangement also provides a technical advantage in that both pot and lid can be moulded in straightforward 'up and down' moulds. When completed, the toy need not be dismantled immediately: its after use as an attractive floral decoration would give the child an extra sense of achievement.

The Materials. Beetle urea material, with its excellent colour range, is recommended for compression moulding the body and lid; ethyl cellulose—a tough material—for injection moulding the stalk and flower units. For the leaves, the leathery 'feel' and natural elasticity of polythene suggest it as an ideal material.

The B.I.P. Technical Advisory Service will assist industrial designers and manufacturers who use plastics mouldings in their production processes. Advice is freely offered regarding product styling, mould design, choice of materials and moulding techniques. The Service exists pri.narily to assist your own designers and technicians regarding those problems peculiar to plastics mouldings, with which only a specialist can be completely conversant.

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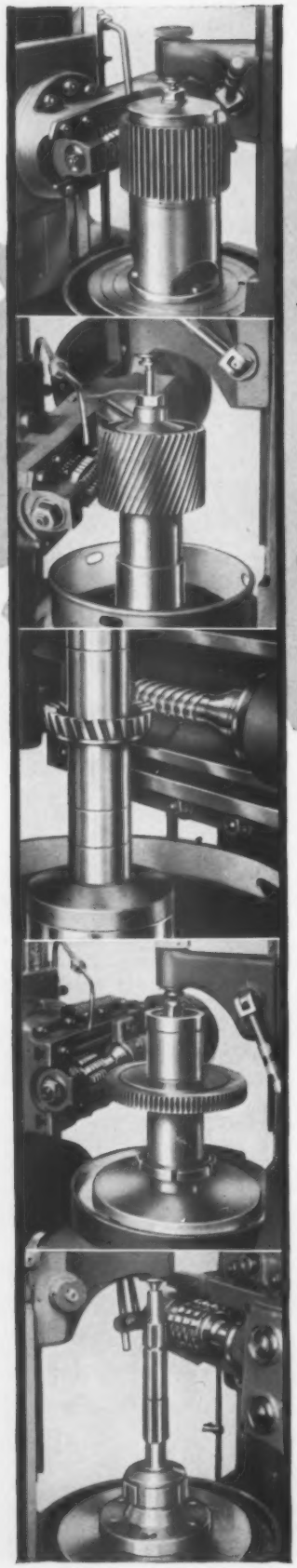
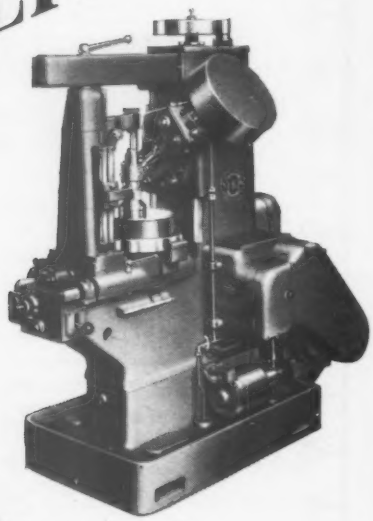


VERSATILITY IN GEAR PRODUCTION



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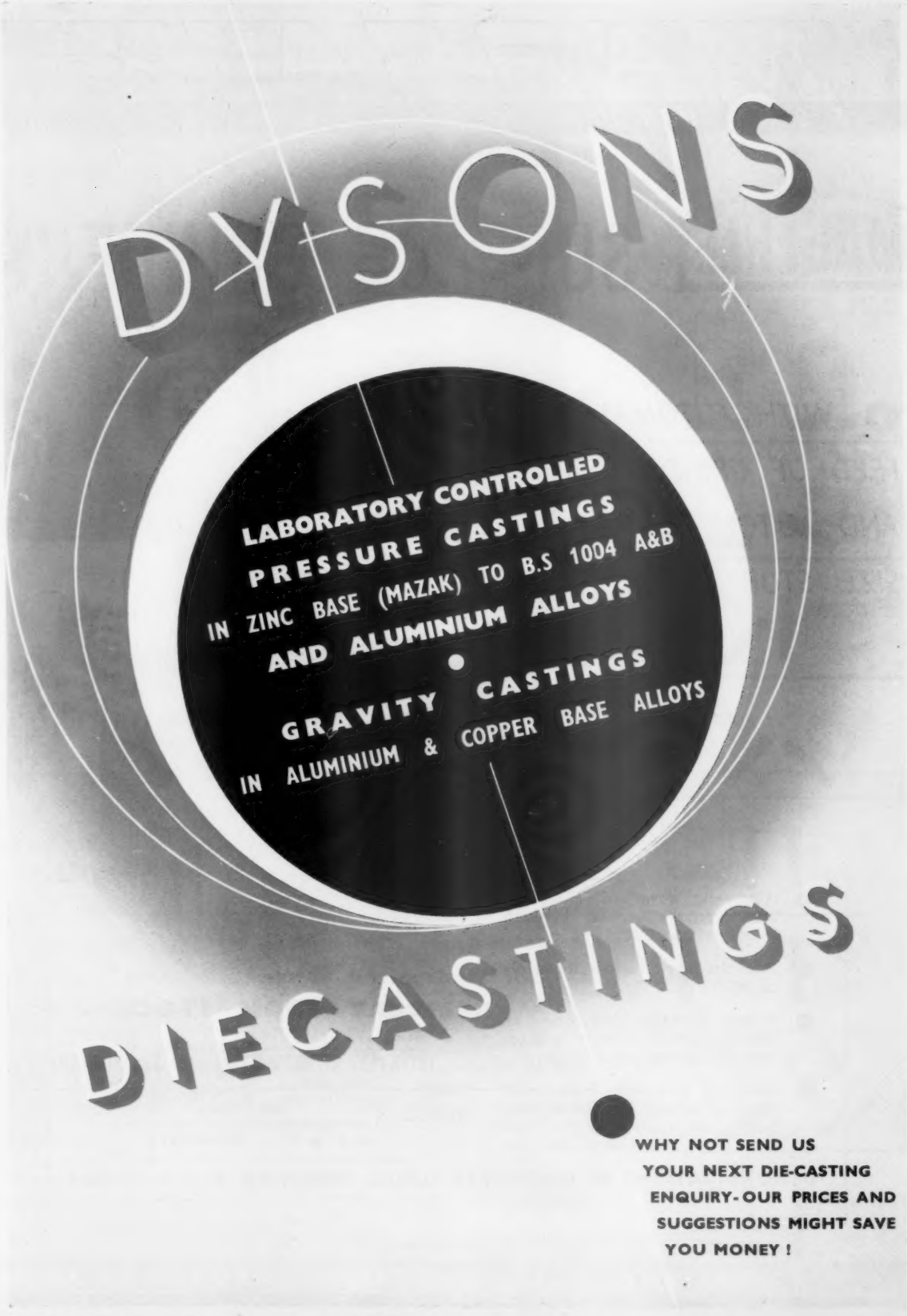

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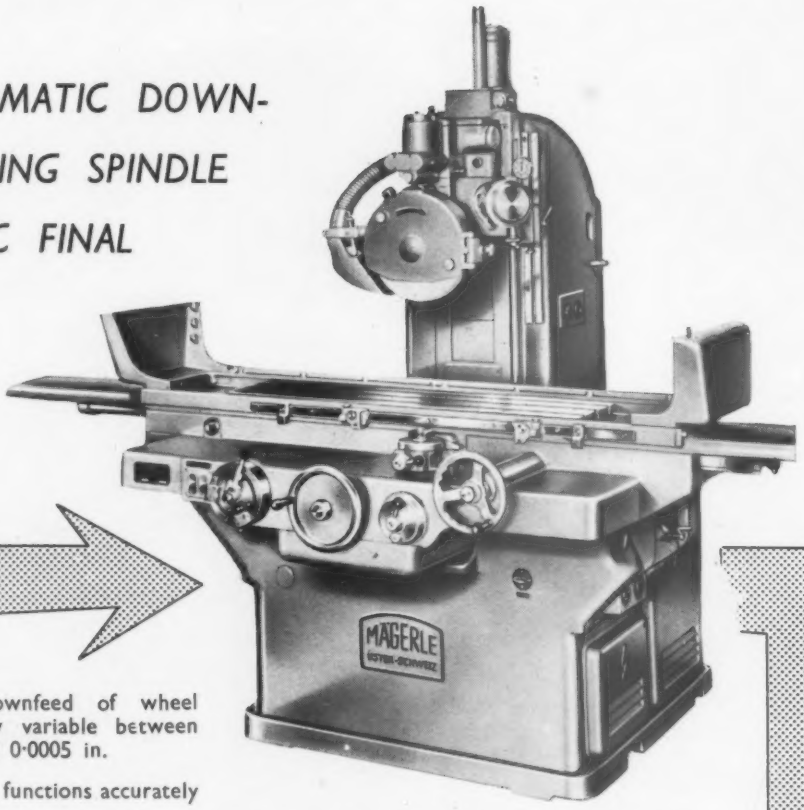

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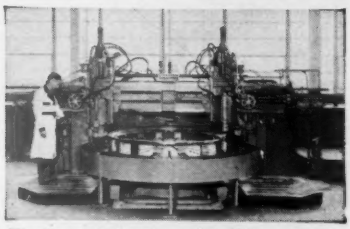

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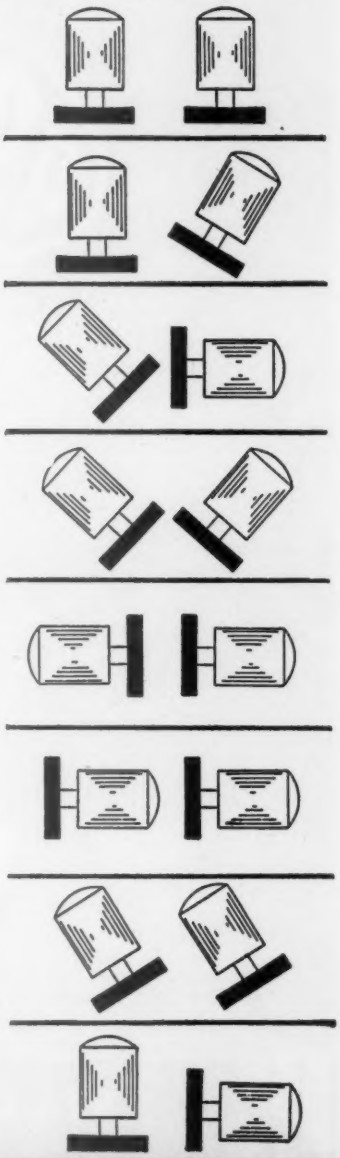

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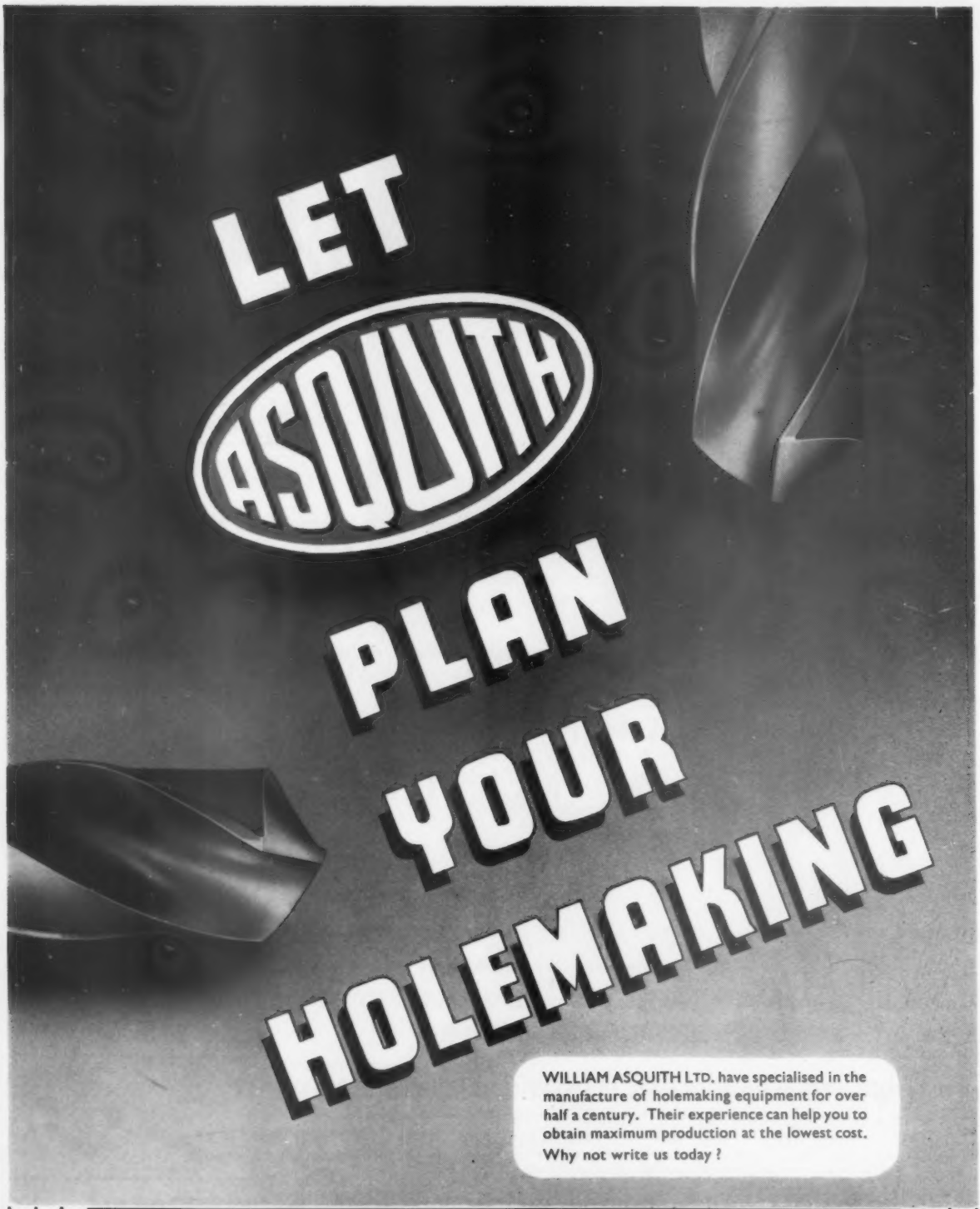
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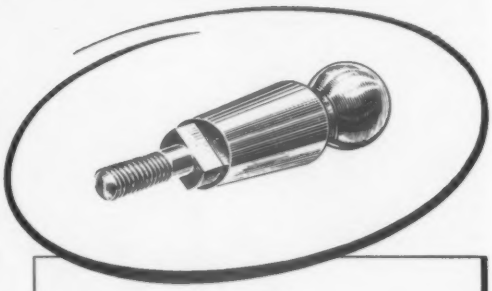

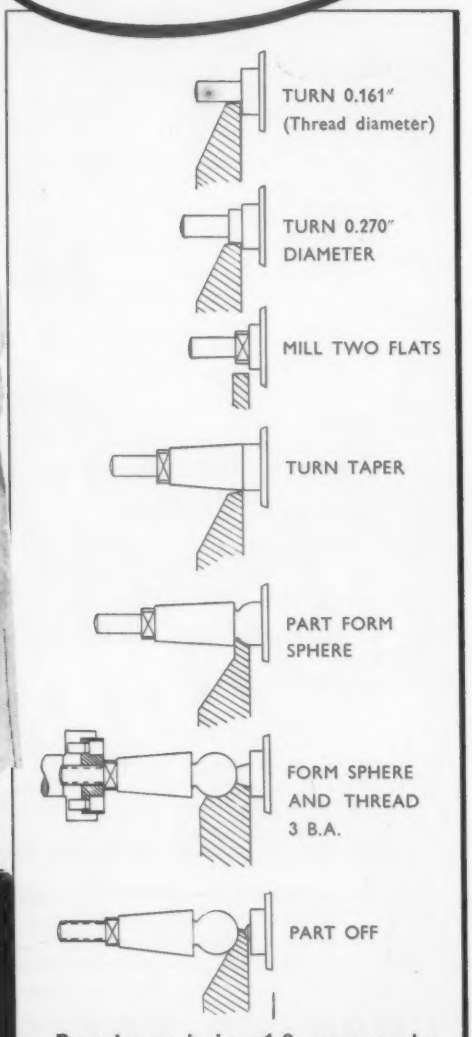

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The Institution of Production Engineers Journal

VOL. 32. NO. 3 MARCH, 1953

Trade Unions and an Expansionist Policy for Production

by SIR VINCENT TEWSON, C.B.E., M.C.,

General Secretary, Trades Union Congress.

Continuing this series of articles on 'an expansionist policy for production', the first of which appeared in the February, 1953, Journal, Sir Vincent describes how the trade unions can contribute towards the implementation of such a policy.

EMPHASIS has already been laid in this series on British industry's need for more capital investment and a widespread and more intensive use of production and work study.

Increasing the productiveness of individual effort with the aid of more and better machinery, and more effectively employing existing production resources—including British workpeople's skill, initiative and experience— is the rational way of improving our economic and social lot. Given the raw materials and the equipment, there is sufficient willingness among all in industry to work enthusiastically towards raising productivity and sustaining our position in competitive markets, which play such a vital part in maintaining a high level of employment.

Mr. Walter Puckey, in a previous issue of the Institution's Journal [1], said ". . . . . when we speak of production, we really speak of the men who practise it." How true this is ! He was very wisely drawing attention to the needs of suitably trained technical personnel for an 'expansionist policy for production.' Without them, expansion would not proceed as we desire; nor would its development be possible without the support of the vast number of workpeople in industry, the great majority of whom are members of trade unions. It is on the shop floor, after all, that management policy seeks expression and where it stands or falls, not only on its technical merits, but also on its reasonableness and acceptability—on its 'human' content.

There can be no hard and fast rules on how these conditions should be met, but joint consultation suggests itself as the obvious framework within which to operate. What better means for management to gain their employees' confidence and demonstrate their integrity ! What better means for workpeople and their organisations to express their point of view, a right which is indisputable if only because of the direct impact of industrial change and developments on the security of their jobs, their earning opportunities and working conditions ! An 'expansionist policy for production', however well organised, will throw up many unforeseen problems and joint consultation, therefore, at workplace and industry levels becomes more imperative than ever.

In stressing this view, trade unions are not begging favours or seeking merely to be kept informed—they believe they have a genuine contribution to make regarding the formulation and implementation of industrial policy aiming at efficiency. They believe, as indeed do many employers, that joint consultation is the way to enable industry to play its vital rôle in sustaining Britain and her people now and in the future.

At the national centre and in the regions, consultation between the government and the two sides of industry has operated successfully over a decade. An outstanding and perhaps more spectacular example of national and international co-operation between employers and trade union organisations, has been the Anglo-American Council on Productivity. This trans-Atlantic exchange of 'know-how' has uncovered tremendous industrial goodwill and potential lines of action.

1 February, 1953.

The influence of the Council and particularly of the 66 Productivity and Specialist Teams, composed of representatives from supervisory, technical and operative grades, has been considerable. Justifiably, perhaps, the Council could claim to have helped fashion the climate of opinion which seeks to expand and increase the rate of industrial development.

Over the past few months, the U.K. side of the A.A.C.P. has merged into the British Productivity Council and, as was the case with the former body, the trade union movement is playing an active rôle. Part of the work of the new Council will be to follow up the Productivity Reports, with a view to securing full consideration, by both sides of each industry concerned, of Team recommendations and suggestions. Already follow-up reports from a number of participating industries indicate a distinct acceleration in O.P.H. and development. This is the very essence of an 'expansionist policy for production'. All the talking in the world, all the reports and literature imaginable, count for nothing until there is action, effective action, at the point of production.

The British Productivity Council intends operating, however, on a wider front than its predecessor and sub-committees are at present discussing a programme of activities to put before a Conference on 19th March for detailed discussion and criticism—as a programme which, throughout the country, will further the cause of increased industrial efficiency.

We, on the trade union side, hope that one activity which will emerge will be a system of exchange visits between plants by small groups drawn from supervisory, technical and operative grades. The idea stems from the A.A.C.P. Team programme, in particular from the briefing tours which each Team made of their own industry in this country before proceeding to their investigations in the U.S.

Inter-plant visits have tended in the past to be regarded with some caution. But the briefing tours brought out clearly the goodwill and spirit of co-operation which exist in industry and of which advantage should be taken. More than one Team member has been heard to say that they learnt more looking round their own industry than they did in the U.S. This may be an exaggeration; on the other hand, a number of Teams have reported that the most efficient firms in Britain compare favourably with their opposite numbers across the Atlantic. We have the information, apparently, but it does not get around! Increasing the velocity and the area of the circulation of 'know-how' is a vital requirement for an 'expansionist policy for production'.

With a constantly and rapidly changing industrial pattern the rôle of the trade union will be, as ever, the safeguarding and advancing of their members' interests; sometimes nationally, in the interests of maintaining a high level of employment, sometimes at the industry or plant level. The environment in which they function may, of course, alter—it is inevitable—but the trade union movement is not without flexibility and commonsense. Work study and scientific management techniques are increasingly being used in industry, and unions appreciate well enough that to represent and protect their members effectively and to express their views adequately in joint negotiations and discussions, knowledge of the techniques is essential.

Training at one-week courses is provided, therefore, at the T.U.C.'s Education Centre at Clapham. Nearly 400 trade union officers have passed through this short but intense course covering management and production subjects. Some officers have received advanced training with firms of industrial consultants. In addition to the T.U.C.'s facilities, individual unions are spending time and money training their officers and members. Of particular note are the one month full-time courses on industrial relations and work study subjects, initiated by the National Union of General and Municipal Workers. These courses have been organised in conjunction with university and technical college authorities in more than a dozen industrial centres, and nearly one thousand shop stewards and members have so far attended.

All this is designed to enable trade unions and trade unionists to carry out their responsibilities to their members and to the national well-being. It is interesting to note that an instance in which men have refused to operate improved machinery soon becomes headline news. From this, we can infer that they are sufficiently isolated to be matters of special comment. That is an indication of how far we have travelled.

An intelligent and 'human' Expansionist Policy for Production will find the Trade Union Movement and its members prepared to throw in their weight.

THE TECHNIQUE OF CARBIDE TOOLING

by LAWRENCE K. LORD, B.Sc., A.M.I.Mech.E., Grad.I.Prod.E.

Presented to the Bombay Section of the Institution, 8th August, 1952.

Mr. Lord served his apprenticeship with Wickman, Limited, Coventry, both in the Wimet Division and the Machine Tool Division of that organisation.

In 1943, he gained the first of the Wickman University Scholarships awarded to senior apprentices and, after resuming academic studies interrupted by service with R.E.M.E., Mr. Lord graduated with Honours in Mechanical Engineering at the University of Birmingham.

On his return to industry, he was employed in the Machine Planning Department of Wickman Limited, until 1948, when he joined his Company's Export Department with the appointment of Machine Tool Specialist.

Mr. L. K. Lord.

THE first of these two Papers[1] dealt with the way in which tungsten carbide was manufactured by powder metallurgy processes. To recapitulate the manufacturing process would take too much time here, but for the benefit of newcomers I have prepared a series of diagrams which schematically outline the processes involved. Briefly, carbide shapes can be made by any one of four processes according to the complexity and form of the desired result. These four processes are shown diagrammatically in Fig. 3. The starting point for the physical operations is, in all four cases, mixed powdered metal, either a tungsten carbide-cobalt mixture, or a tungsten carbide-titanium carbide-cobalt mixture. The way in which these two mixtures are obtained by chemical processes from the powder manufacturer's raw materials, is shown diagrammatically in Figs. 1 and 2. Fig. 1 shows the reduction, carburisation and binding of the straight WC-Co grades, which it will be recalled are adequate for the machining of cast iron and non-ferrous metals, and for wear resistant applications. Fig. 2 shows the metallurgical stages in the manufacture of the WC-TiC-Co grades, which were shown to be necessary for machining steels and similar materials which tend to weld-on to straight grade tips. The figures are purely diagrammatic, but may clarify the production sequence of the finished tips and shapes.

To derive the fullest advantages which tungsten carbide, the hardest metal made by man, is capable of conferring, in practically every industry, the basic principles controlling cutting tool design and application must be understood. The purpose of this present Paper is to throw some light on these principles, and on their practical realisation.

TOOL DESIGN

Terminology

Until international standardisation is arrived at, the terms which are used in this Paper conform to those adopted by the majority of British toolmakers, and which are shown in Fig. 4. The diagram is self-explanatory, the only point requiring emphasis being that the tool shown is a right hand tool. The hand of a tool is the side on which the cutting edge lies, when viewed from above with the cutting end of the tool towards the viewer.

1. "The Nature of Tungsten Carbide." This Paper is available to members on loan from the Hazleton Memorial Library.

POWDER MANUFACTURE

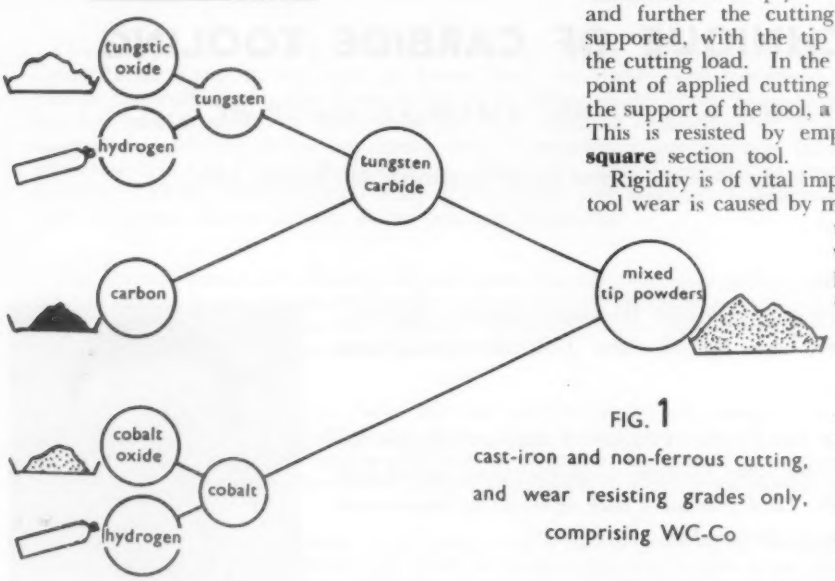


FIG. 1

cast-iron and non-ferrous cutting, and wear resisting grades only, comprising WC-Co

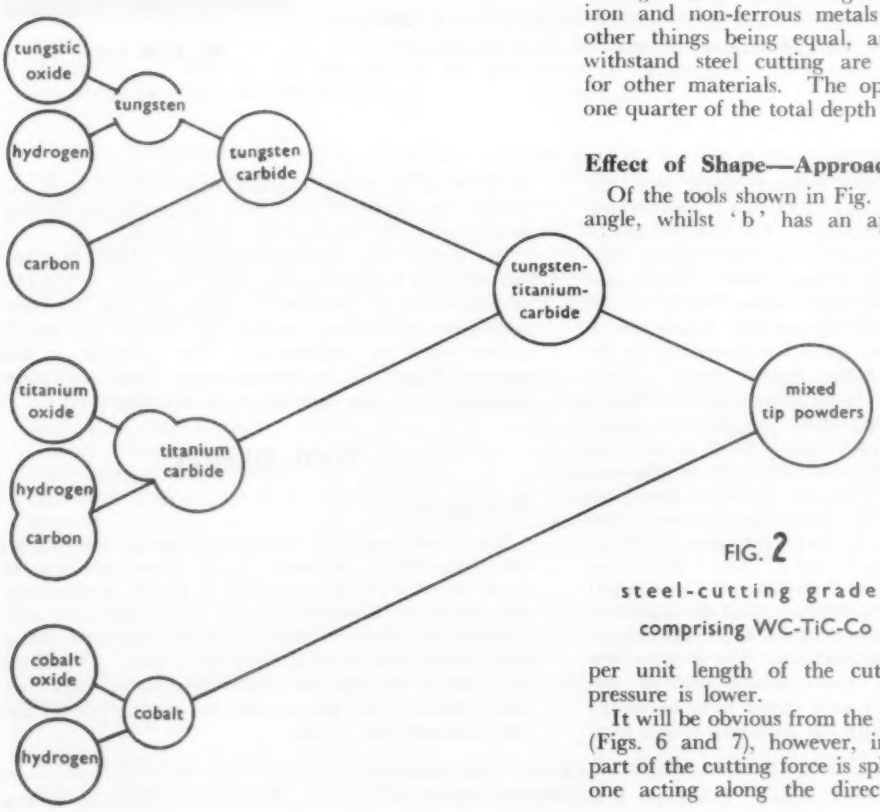


FIG. 2

steel-cutting grades comprising WC-TiC-Co

Tool Size and Tip Size

The fundamental requirement in carbide tool practice is ample rigidity. To achieve this the tool shank must be amply strong so as to absorb vibration, and further the cutting edge must be adequately supported, with the tip sufficiently thick to absorb the cutting load. In the case of cranked tools, as the point of applied cutting pressure is not in line with the support of the tool, a twisting effect is introduced. This is resisted by employing the largest possible **square** section tool.

Rigidity is of vital importance to tool life, because tool wear is caused by minute vibrations of the tool, undetectable to the eye, which cause the cutting point to rub the work with a high frequency oscillation which wears away the cutting point.

In practice, the deepest possible shank should be used for all carbide tools. In designing tools, the tip thickness should not be so great that the depth of the supporting shank is reduced excessively, but neither should the tip be so thin that it will not absorb the cutting load. The cutting load in the case of cast iron and non-ferrous metals is less than for steel, other things being equal, and so tips which will withstand steel cutting are suitable dimensionally for other materials. The optimum tip thickness is one quarter of the total depth of the tool.

Effect of Shape—Approach and Trail Angles

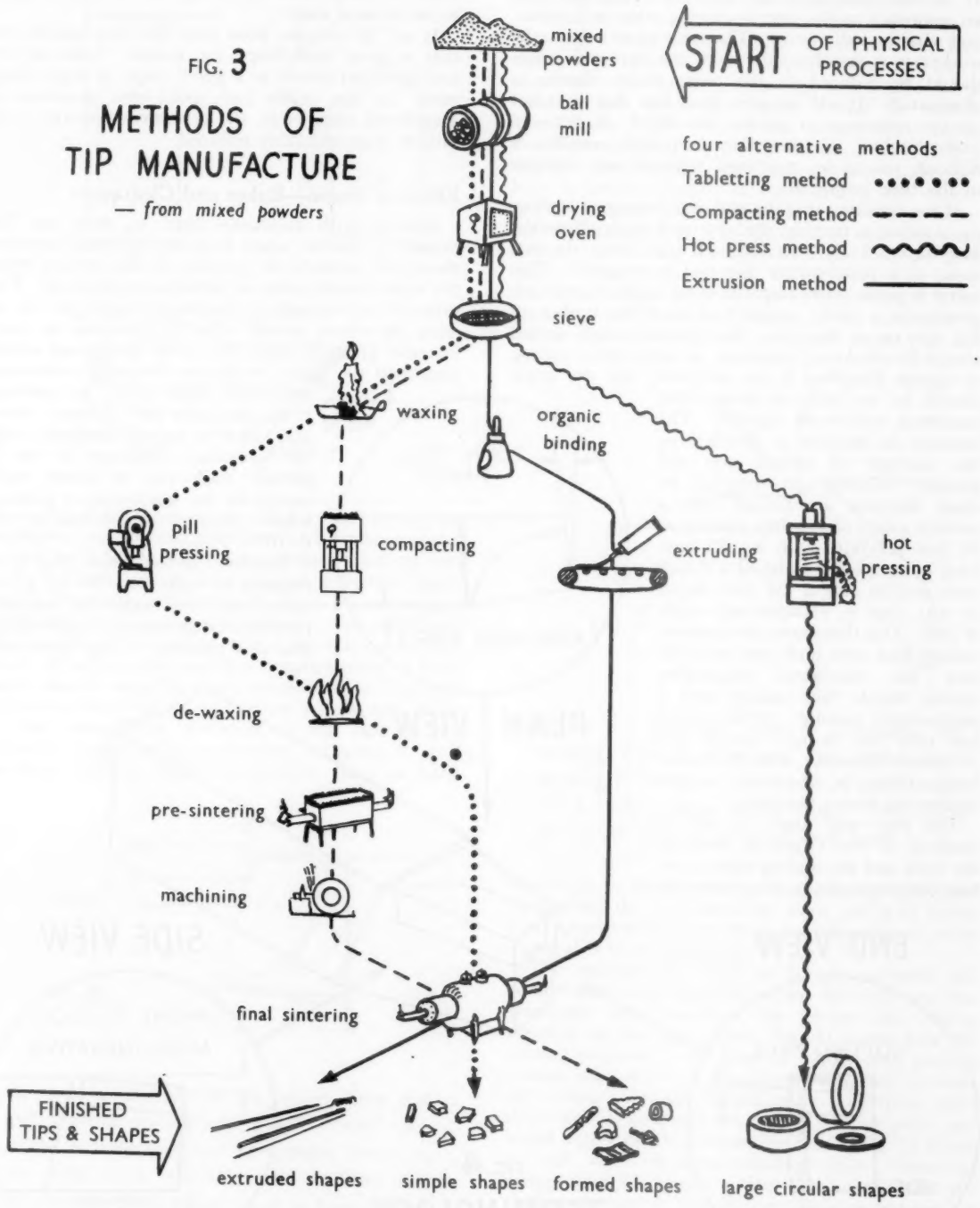
Of the tools shown in Fig. 5, 'a' has no approach angle, whilst 'b' has an approach angle of 45°. Although each has the same depth of cut, and the same feed, so that both will remove the same amount of material in the same time, the tool with the 45° approach angle uses less power and is also likely to have a 20-25% longer life between regrinds. This is because, without any reduction in volume removed, the tool with the approach angle forms a longer and thinner chip, so that per unit length of the cutting edge, the cutting pressure is lower.

It will be obvious from the parallelograms of forces, (Figs. 6 and 7), however, in which the horizontal part of the cutting force is split into two components, one acting along the direction of feed, and one

FIG. 3

METHODS OF TIP MANUFACTURE

— from mixed powders



transversely at right angles to the feed, that the greater the approach angle (Fig. 7) the greater the transverse force which tends to bend the workpiece. If slender workpieces are machined with too high an approach angle, that is exactly what will occur, and chatter will result. Thus, for cases where the workpiece is insufficiently rigid, the approach angle should be reduced to the point where chatter is eliminated. It will be seen from this that it is not always necessary to reduce the depth of cut,—an understanding of this fact frequently enables a difficult job to be machined without any increase in the time required.

When breaking into the end of a forging or casting, preparatory to turning, the approach angle allows the first impact to be received well back from the tool nose, at a point where the tool is stronger. This factor is particularly important, for without any such protection a costly tipped tool could be broken in this way on its first job. An approach angle should always be employed, therefore, in cases where cutting to square shoulders is not essential, and the angle should be as large as practicable consistent with work rigidity. The extreme in practice is afforded by the example of chilled iron roll turning. Chilled iron rolls of 88 shore hardness are turned with a suitable grade of tungsten carbide at 18 feet per min. with a .035 inch feed, using the full width of a 2 inch wide tool to give a .25 inch depth of cut; that is, an approach angle of 75°. This distributes the extreme cutting load with such hard material over the maximum practicable cutting length, thus making such a performance possible. With chilled iron rolls (the example quoted was 14 inches diameter and 35 inches long), there is of course ample rigidity for such a practice.

The plan trail angle, it will be recalled, is the clearance between the work and the trailing edge of the tool; the lower this is, the greater the support given to the tool point, to enable it to withstand the backwards component of the cutting force. In tool designing, the plan trail angle should be as small as convenient—6°being a practicable minimum in most cases.

It will be obvious, from what has been said so far, that a good tool shape for carbide bears no resemblance whatever to a good shape in high speed steel. In fact, unless high speed steel procedure is abandoned completely, the certainty of success with carbide is considerably reduced.

Effect of Shape—Rakes and Clearances

Dealing with clearances first, as these are the simplest to discuss, apart from the fact that excessive clearances weaken the support of the cutting edge, the main consideration is subsequent grinding. The principle of secondary clearances under the tip to allow the silicon carbide wheel to grind the tip only, increases grinding wheel life, as the steel shank would soon load the wheel leading to frequent re-dressing and rapid wheel wear. In practice, a tip clearance (i.e. primary clearance) of 4° is usually adequate, with the secondary clearance 2° to 4° greater than this in every case, except for the machining of plastics, which require clearances of up to 10°.

The front to back angle (Fig. 4), is negative on tools made by my Company, since our extensive research confirms the theoretical consideration that this provides a chip formation

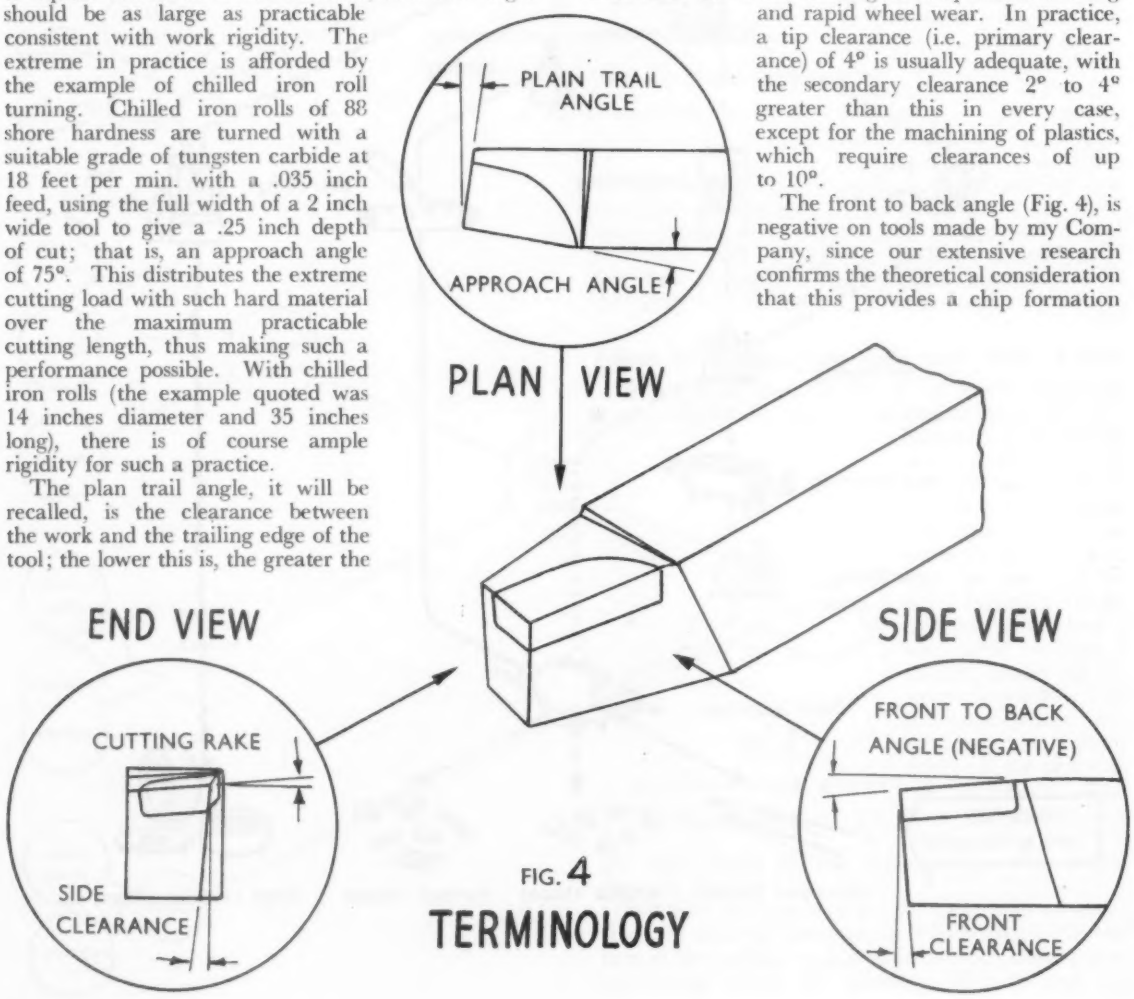
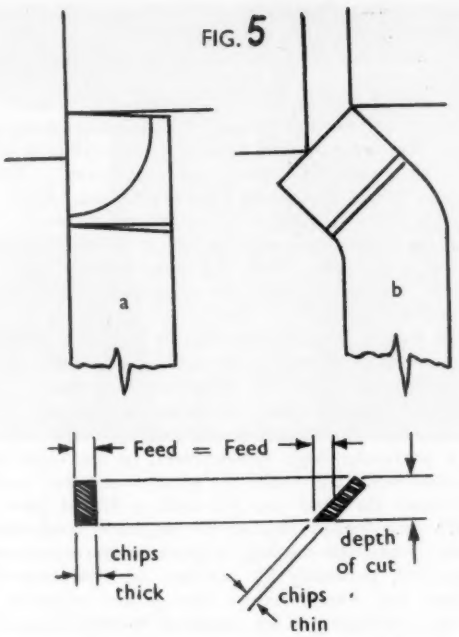


FIG. 4
TERMINOLOGY



which tends to constrain the chip to curl frrom the workpiece surface, and thus prevent scratching of the surface in finishing cuts. Since certain finishing cuts with tungsten carbide can provide a surface finish which frequently eliminates the need for subsequent grinding, this is a valuable feature. An additional effect is illustrated in Figs. 9 and 10 which show two tools, the upper one having a negative front to back angle and the lower having a positive angle. The chip pressure, normal to the tip surface, will be seen to be exerted away from the work in the case of the negative angle, thus preventing digging-in and resultant chatter, whilst the positive front to back angle tool (Fig. 10) induces a chip pressure which acts in a direction such as to push the tool point into heavier contact with the work, inevitably increasing front clearance wear and shortening tool life.

It should be realised that the common practice of stopping a lathe with the tool in cut and the feed engaged is disastrous to tipped tools, and it is imperative to impress upon operators that when carbides are used that habit should be broken immediately. However, if this occurs unavoidably, due for example to a power failure, a tool with a negative front to back angle and a negative rake, will have a greater chance of withstanding the ordeal.

The cutting rake is of considerable importance, and a glance at Fig. 4 is suggested in order that the cutting rake is not confused with the front to back angle. The cutting rake is virtually the angle measured at right angles to the cutting edge (it is the angle measured in the direction of the feed only in the case of tools with zero approach angle). It will be seen to be the angle which plays the greatest part in shearing the chip from the work and it is, therefore, largely determined from consideration of what material is to be machined.

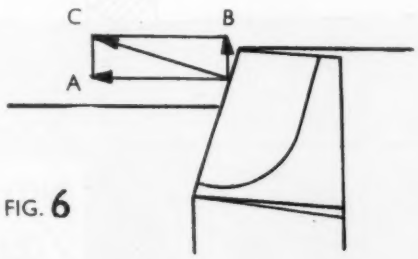


FIG. 6

'C' is horizontal part of the cutting force, and this depends primarily on metal removal rate. It can be split into two component forces :— 'A', axial force, which is easily resisted, and 'B', bending force, which tends to bend slender work. Only small approach angles should be used with slender work (see fig. 7).

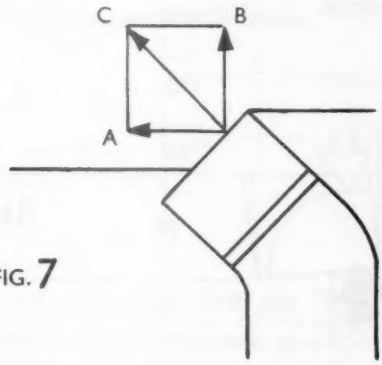


FIG. 7

When the approach angle is increased, the bending force is increased. As shown here bending force 'B' is over twice original value, for a cutting force shown equal. This force 'B' would tend to bend slender work.

The tougher the material being machined, the greater the power required to part the chip from the workpiece and, therefore, the greater the cutting pressure on the tool. Now, Fig. 11 shows how the cutting pressure, in the case of a tool with positive cutting rake, acts in a direction which tends to shear the cutting point off the tool itself; the cutting point is not unduly strong in the case of positive rakes, and is less supported the greater the rake. Fig. 12 shows a tool with negative cutting rake, somewhat exaggerated for clarity. Note how in this case the cutting pressure is directly into the strongest part of the tool, and how the negative rake strengthens the cutting edge by increasing that section which has to withstand the shearing action of the cutting force.

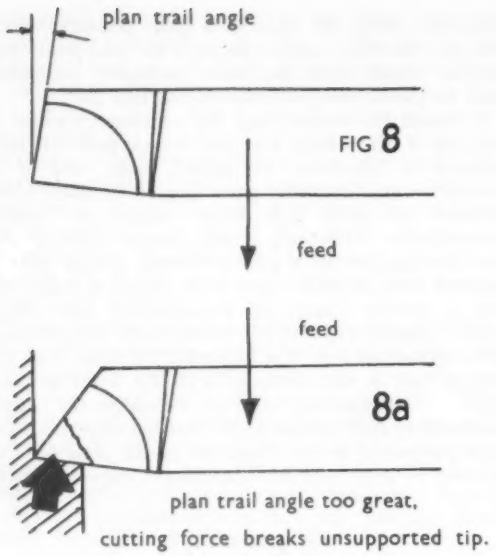
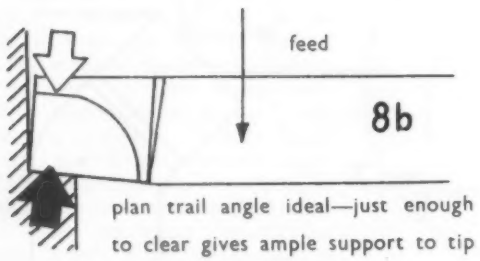


FIG 8



Quite apart from mechanical strength arising out of the support provided by negative rakes, another glance at Fig. 11 will show that the cutting pressure exerted on a positive rake tool forces the tool into the work, and causes additional rubbing on the front clearance. This is where a breakdown of a cutting edge invariably begins. Negative rake, on the other hand, (Fig. 12), provides a direction of cutting pressure which tends to thrust the tool away from the work, so reducing front clearance wear, and contributing to an increase in tool life between re-grinds.

To summarise the argument so far, materials such as high-tensile and alloy steels require negative cutting rakes to withstand the heavy chip pressures that these materials exert. The greater the tensile strength of the material, the greater the negative cutting rake required. Conversely, the greater the machinability of the material, the higher the positive rake which may be employed. Positive rakes permit less power consumption for a given metal removal rate, but the life between regrinds of positive rake tools is generally less, all other things being equal, due to their weaker cutting edge support. For materials such as cast iron, mild steel and light alloys, therefore, which exert lower cutting pressures, increasing positive rakes should be used, up to the point of economical tool life. Fig. 13 shows a range of materials in order of machinability, with appropriate cutting rakes.

It has been shown that negative rakes are necessary for the machining of high-tensile materials. It has also been implied that the greater the negative rake, the greater the horsepower consumed. This is obvious when the matter is considered, since the chip has to be deflected through a greater angle, and then has to slide over the top face of the tool climbing the negative rake. The friction between the chip and the top face absorbs the extra horsepower which has to be provided.

The power consumption can be reduced, whilst at the same time retaining the cutting edge advantages of negative rake, by employing primary and secondary cutting rakes as shown in Fig. 14. The primary rake is at the required negative angle, say 3° for a particular high tensile steel, in the form of a negative land, the width of which need not exceed four times the feed (i.e. 0.1 inch width of land for a .025 inch feed). Behind the negative land, which actually does the cutting, a positive secondary rake is applied, generally 8° positive, to eliminate chip friction and hence reduce the power absorbed in this way, releasing it for more useful employment in increasing the metal removal rate.

The best tool section for most steels other than mild steels, particularly for intermittent cutting and roughing cuts on forgings is, therefore, along the lines of the tool shown in section in Fig. 14. Correct carbide tool shapes appear very odd to those steeped in HSS practice, and once again it is necessary to

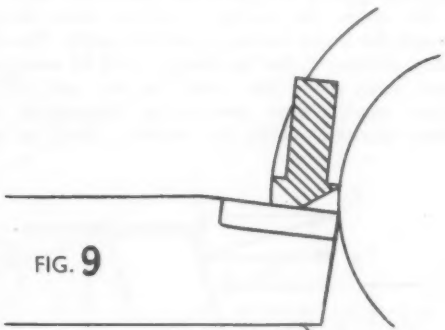


FIG. 9

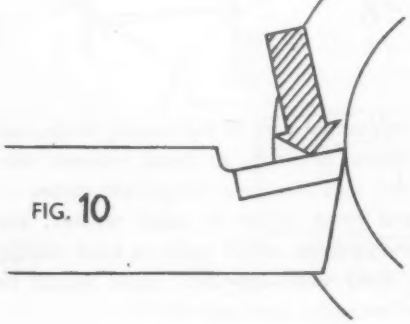


FIG. 10

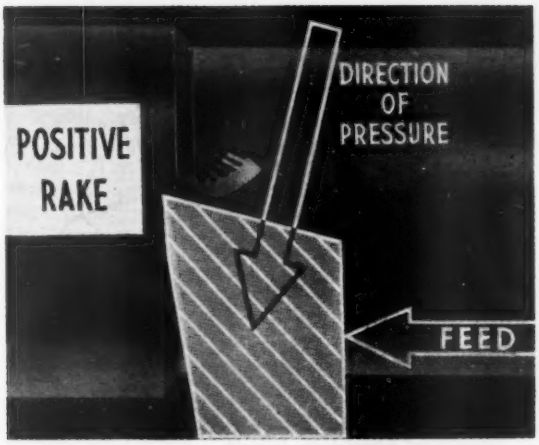


Fig. 11

emphasise that every vestige of the old HSS techniques must be cast aside for optimum carbide performance.

Effect of Nose Radius

A large nose radius absorbs too much horsepower, and although round-nose tools are extremely useful and adaptable, they should be used only for relatively light cuts, or on low tensile materials which produce low cutting pressures, unless unavoidably required for forming radii, such as in roll grooving. Additional power is absorbed, because to curl a curved chip requires greater effort than to curl a flat chip, since the resistance to bending of the curved chip is very much higher than that of the flat chip. This can readily be appreciated by supporting a weight on a curved card (Fig. 15). The flat card will support practically no weight—its resistance to deformation is low, and hence the flat chip can be curled off from

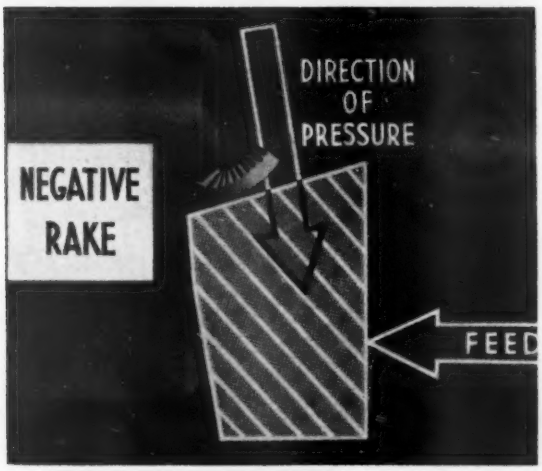


Fig. 12

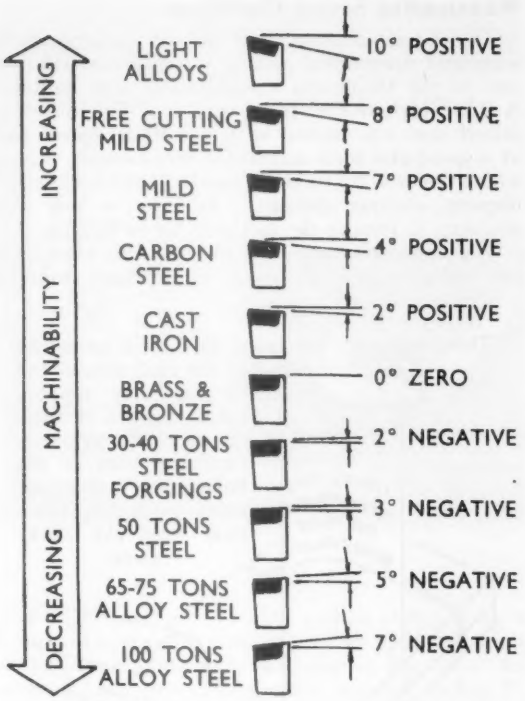


FIG. 13

the workpiece with ease whilst the curved chip (represented in Fig. 15 by the curved card) resists deformation, and thus absorbs more power in being parted from the workpiece for equal metal removal rates. Even if this power is available, it is pointless and uneconomical to use it in such a way, when it can be usefully employed in increasing the metal removal rate by increasing the feed and depth of cut.

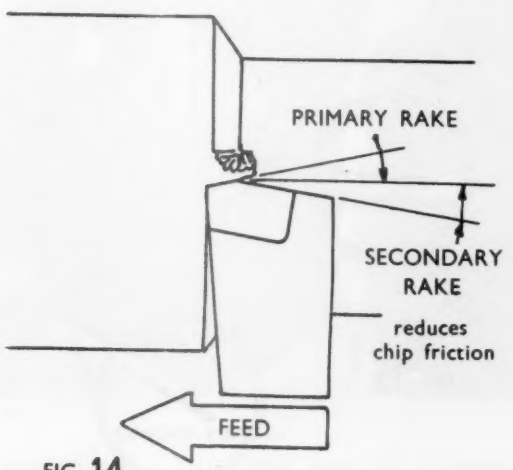
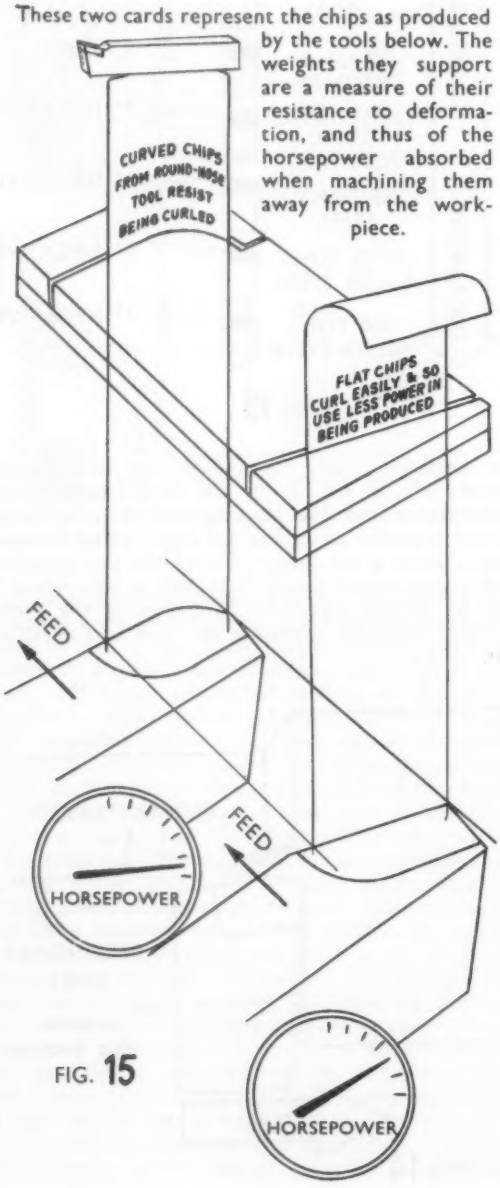


FIG. 14

Withstanding Severe Conditions

The way in which tungsten carbide can successfully withstand interrupted cutting is a practical vindication of the theoretical considerations just outlined. A 0.5% carbon steel billet with four longitudinally milled slots was turned with a carbide tipped tool at a speed and feed normal for the material, during which time the tip received nearly 32,000 very severe impacts without damage. In fact it was not necessary to remove the tool even for re-lapping.

The approach angle was 45° and this allows the first impact to be taken up the tip well back from the tool point, in a stronger part of the tool (Fig. 16). The tool shape shown here, which was subsequently used for maximum life on the slotted billet demonstrations, may appear unorthodox at first sight. It is a heavy duty shape introduced by my Company for very heavy turning, facing and boring operations, where machine and workpiece rigidity and power available are adequate to permit full exploitation of tungsten carbide. The tool is developed from the familiar cranked turning and facing tools (Fig. 7), but with the corners buttressed by trail angles of 15° to provide maximum resistance to tool pressure under heavy loads in either direction.


These two cards represent the chips as produced by the tools below. The weights they support are a measure of their resistance to deformation, and thus of the horsepower absorbed when machining them away from the workpiece.
CURVED CHIPS FROM ROUND-NOSE TOOL RESIST BEING CURLED
FLAT CHIPS CURL EASILY & SO USE LESS POWER IN BEING PRODUCED
FEED
FEED
HORSEPOWER
HORSEPOWER
FIG. 15

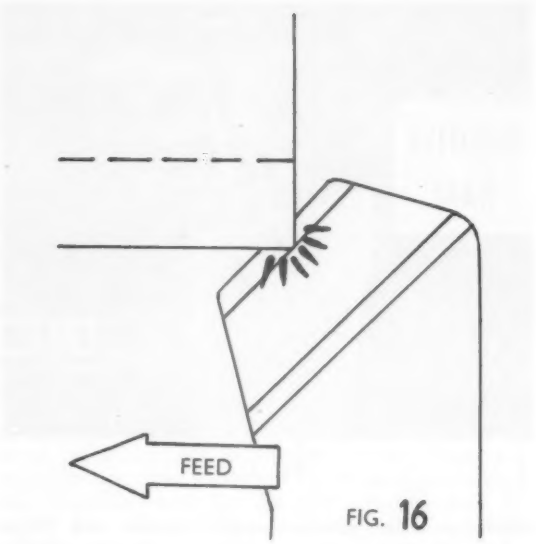


FIG. 16

The primary cutting rake was 4° negative, giving a stronger cutting edge which accepts the impacts due to the slots, well back from the cutting edge towards the strongest part of the tool.

Finally this tool had a negative front to back angle of 4°, which acts in a similar manner in providing that the impact is taken where it can be better resisted, as shown in Fig. 17, which is a simple bar turning tool, for clarity.

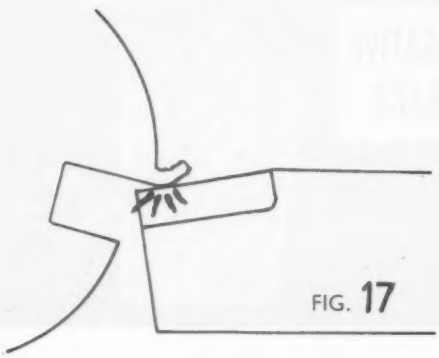


FIG. 17

Multi-point Tools

So much for the basic principles of tool design. Only single point tools have been dealt with, but it will be appreciated that the same principles apply to milling cutters also. A milling cutter is simply a succession of single point turning tools in a rotating holder. The terms used are necessarily different, but simply related. As shown in Fig. 18, the radial rake in a milling cutter is equivalent to cutting rake on a turning tool. Similiarly, Fig. 19 shows

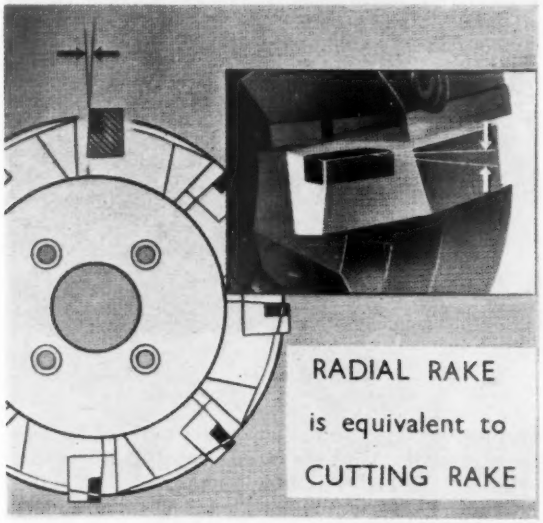


Fig. 18

that the helix angle in a milling cutter is equivalent to the front to back angle on a turning tool. These angles can be positive, zero or negative, depending on the materials being machined, exactly as in single

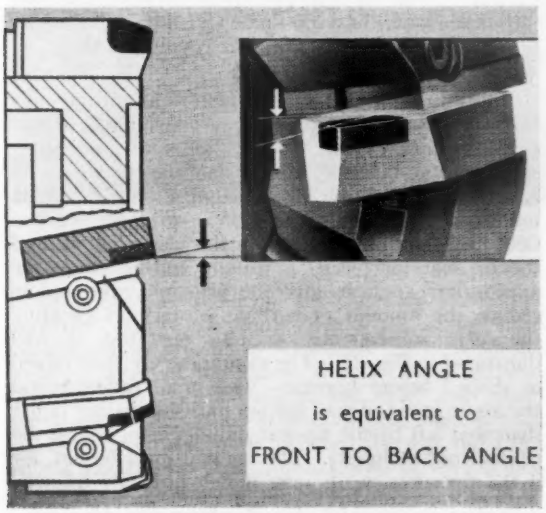


Fig. 19

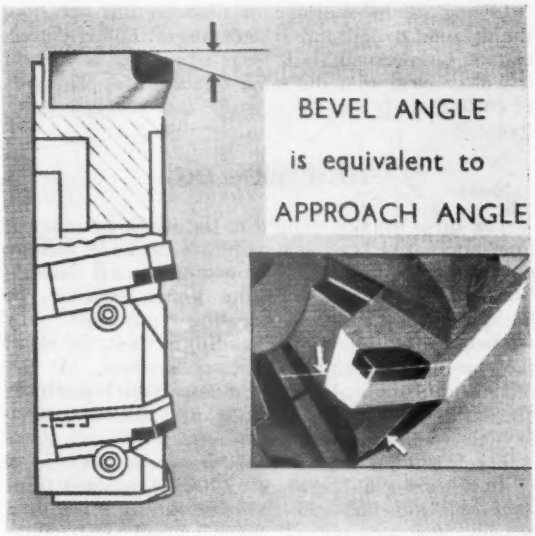


Fig. 20

point tool practice. Finally, milling cutters have a bevel angle, which corresponds to the approach angle of the single point tool, as shown in Fig. 20. An inserted blade face milling cutter is shown in Fig. 21. The helix angle (which is 10° negative) the bevel angle of 15° and the 10° positive radial rake are all visible on the solid carbide blades.

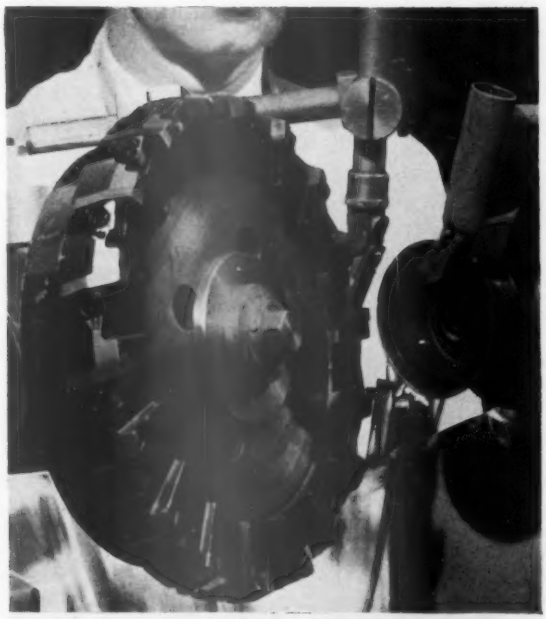


Fig. 21

Reconditioning an inserted-blade cutter with a diamond impregnated resin bonded lapping wheel.

Owing to the shortage of time on this occasion, the detailed design and application of milling cutters cannot be pursued, but from what has been said it will be clear that the same fundamental principles of cutting apply exactly as in the case of single point tools.

TOOL BRAZING

The tip is usually secured to the shank by brazing. Four alternative brazing systems are available, namely oxyacetylene torch brazing; gas or electric furnace brazing; electric resistance tool tipping machine; or high frequency induction heating equipment. For the occasional tipping of a handful of tools, the small shop need only employ the torch method. At the other end of the scale, my Company, which produces about 3,000 tools each working day, uses a battery of high frequency induction heaters.

The brazing materials available are Easy-flo No. 3 (with a brazing temperature of 700°C), in sheet form .003 inch and .005 inch thick, or Sifbronze (with a brazing temperature of 900°C), and electrolytic copper (with a brazing temperature of 1100°C) also in sheet form. The choice of brazing material is governed by many considerations. If torch brazing is the only method available, then copper cannot be used, as this has the highest melting point. Further, where difficulties are likely to arise from the high differential thermal expansion between steel and tungsten carbide, the simplest way of helping to overcome these is by using the brazing material with the lowest melting point. Again, it may be required to tip HSS shanks, as for example in high duty

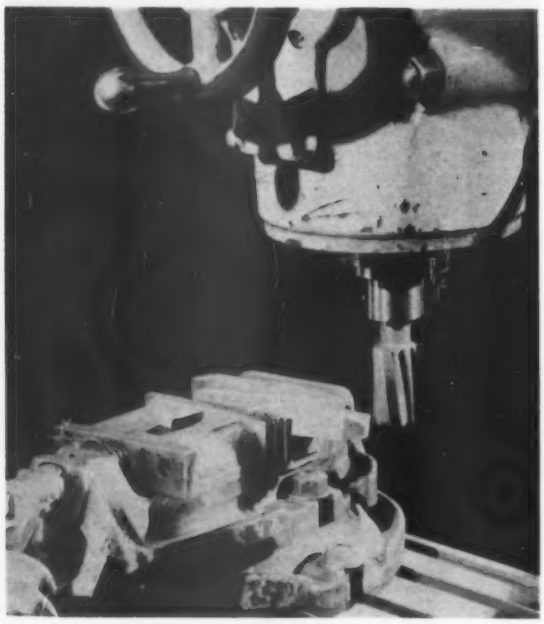


Fig. 22
Milling the tip seat.

Fig. 23
Torch brazing a simple tool.

parting tools, as these shanks are stiffer. In such cases Easy-flo must be used, since if copper is employed the higher brazing temperature will soften the HSS. Conversely, in brazing reamers, for example in which it is often required that the shank and flutes behind the tip are to be hard, it is necessary to braze with Sifbronze or copper, otherwise during carburising for shank hardening, the carburising temperature will unstick the tips. Copper brazes are commonly used for large section tools, but have to be furnace brazed, being beyond the scope of the torch method. The fluxes used are Easy-flo flux for Easy-flo brazing, Easy-flo flux or Sif-flux for Sifbronze brazing, and unfused borax for copper brazing.

Torch Brazing

The procedure for tipping a normal turning tool by the torch process should cover the requirements of the majority of the small or medium sized workshops in this country * whose consumption of tools is not more than say 20 or 25 per day. The shank material recommended is 0.35% to 0.4% carbon steel (certainly no milder than the lower figure), and the tip seat (or recess) is usually end-milled at the appropriate angle to give the principal rake and so reduce the amount of carbide wastage in grinding the rakes subsequently. This operation is well illustrated in Fig. 22. The clearances are then milled or shaped before brazing. The small radius round the lower inner edge of the tip must be slightly larger than that left by the tip-seat milling, or of course the tip will not fit snugly. The tip seat must be flat, for if the tip rocks on its seat, it will probably fracture

* Readers are reminded that this Paper was presented in India.

in service because its upper face will be in tension during cutting. The tool shank is set up in a bench vice with the tip seat projecting horizontally or slightly backwards as shown in Fig. 23.

The Easy-flo No. 3 sheet is cut to shape with shears or scissors so that when required it will drop into the tip seat, and a strip of sheet is cut to provide brazing material at the back of the tip.

The surfaces of the tip which will be in contact with the braze are lightly linished, and the tip, the Easy-flo sheet, and tip seat are all brushed with carbon tetrachloride to remove grease collected from the fingers during handling. This operation is of prime importance. The flux is applied over the whole of the end of the shank, and both under and over the brazing metal strips, and the tip laid in position.

The brazing flame must be adjusted to a reducing atmosphere (slight excess of acetylene) with the outer cone about one third longer than the inner cone, the acetylene pressure being not less than 5 lb. per square inch and the oxygen pressure at 10 lb. per square inch. The reducing part of the flame just in front

Fig. 24
Brazing with a high frequency induction heater.

of the inner cone should be used, and the flame kept moving. Apply the flame first of all at the back of the tip to provide a 'reservoir' of heat in the enlarged part of the shank, then at the front and bottom of the shank until at red heat, and finally when the brazing metal is seen to melt, on to the tip at 45° sharing the flame between the top and front of the tip, pressing the tip back into its seat with a file tang or some similar instrument. It should be noted, whilst pressing the tip back, that it actually 'floats' on the braze metal, thus ensuring a

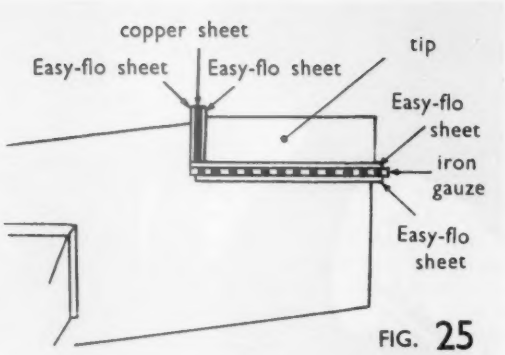


FIG. 25

thoroughly wetted under-surface of the tip. The flame can now be taken away and the tip pressed back and down exactly as shown in Fig. 24, which is actually of an induction brazing operation. This will squeeze out the excess braze metal and the braze will quickly set as the tool end cools to a black heat. When there is no danger of the tip sliding off, the tool should be allowed to cool in graphite powder or in sand (in, not on) so as to ensure slow cooling.

The procedure described is the simplest possible braze, however, particularly suitable for tools such as recessing tools in which the tip goes across the tool, is not longer than say .625 inch and is not enclosed. For tips .75 inch and longer, for irregular tips such as form tools, for enclosed tips and for hard grades and WC-TiC-Co grades, a reinforced sandwich braze is employed. This makes use of soft iron gauze, .003 inch to .005 inch thick, of about .025 inch mesh, which is sandwiched underneath the tip between it and the shank, whilst at the back of the tip a similar 'cushion' is provided by a strip of electrolytic copper. Neither of these stress relieving layers melts during brazing. They are cut up with shears in a similar fashion to the Easy-flo sheet, and two sheets of Easy-flo are used with a sheet of brazing gauze or copper between them as shown in Fig. 25. For particularly highly stressed brazes, thermally or mechanically, molybdenum foil is sometimes used as a stress relieving lamina.

Furnace Brazing

In furnace brazing the assembly, comprising tip and iron gauze for 'difficult' tips has the unfused borax which is used as a flux sprinkled over the top of the finished assembly, not between the components. Two-stage heating, i.e. preheating at the furnace door followed by full heating within the furnace itself, is used, the brazing temperature being between 1150°C and 1200°C. The tools should not be kept in longer than is necessary to melt and distribute the copper, and to 'float' and press the tip into position with a rod, and the furnace atmosphere must be protective. That is, an electric furnace must have a gas curtain, and a gas-fired furnace must employ an excess of gas, so that slightly reducing conditions prevail. An electric brazing furnace in use is shown in Fig. 26. Subsequent cooling is under carbon or sand as in the case of torch brazing.

Fig. 26
Brazing tools in an electric furnace with reducing atmosphere.

Tool Tipper

The use of an electric resistance tool tipper gives rise to no especial problems in the case of tungsten carbide tools. The only points to note are that the abutting electrode bears only against the lower part of the shank under the tip, and not against the tip itself. Easy-flo flux is employed, which is sprinkled in the tip seat before heating commences, to prevent oxidation. Brazing metal is most conveniently applied to the tip seat when it is at red heat by means of Easy-flo No. 3 in rod form say 1/16 inch or 3/32 inch diameter. The tip (which has meanwhile been preheating upside down on the top of the tool shank), is placed in position in the tip seat, and the Easy-flo rod applied to the vertical joints, more flux being applied by means of the rod, to which it readily adheres. The heat can now be switched off, and the tool unclamped for slow cooling in sand.

High Frequency Induction Brazing

High frequency induction brazing is a clean and rapid process ideally suited to the tipping of large quantities of tools. A 7.5 kW set is sufficient for practically all tools likely to be met with up to 3 inches by 2 inches section. The heating time is about 1¼ minutes for the largest tools in everyday use, 2 inches by 1¼ inches section, down to a few seconds for very small tools, although a minimum heating time of about ten seconds is recommended, to avoid thermal shock.

Figure 27 shows a simple set up employing a one-turn inductor for a small batch of special form tools. Easy-flo brazing sheet with Easy-flo flux is used, together with iron gauze and copper sheet stress cushions as described previously. The only difference from the torch brazing technique, so far as the tool-tip braze assembly is concerned, is that the flux is

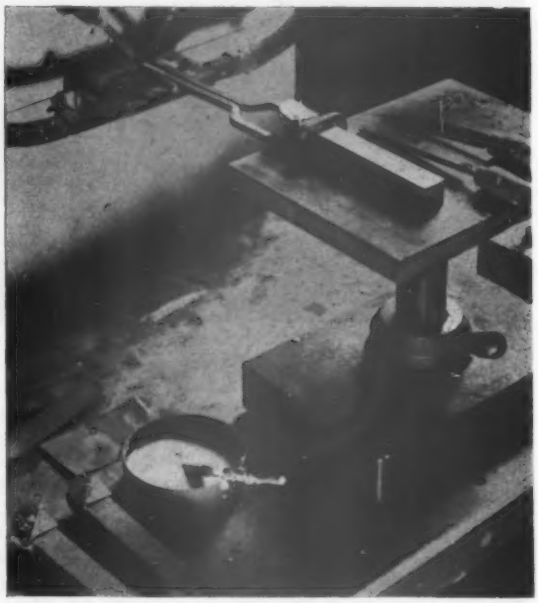


Fig. 27
Brazing with a high frequency induction heater.

made into a paste with distilled water. This feature, together with the brazing sheet and gauze, is shown in the photograph. The use of paste flux renders the made-up tool and tip portable for brazing, and saves time, where large quantities are involved. Fig. 24 shows the tip being floated into position on the molten braze metal, this procedure being just the same whatever heating method is employed.

With the high frequency process, unskilled operators can turn out good and consistent brazes at a rapid rate after only brief familiarisation.

Non-brazed Tips

It is appropriate to mention at this stage that certain tools, notably those used for some of the most rigorous machining conditions in industry, have succeeded only because they are entirely free of brazing stresses. This is achieved by eliminating the brazing operation and using mechanically held tips.

TOOL APPLICATION

After aspects of the design of tools, and a brief reference to their manufacture, the next logical step is their application. Many points of application were discussed earlier in conjunction with design features, in order to justify those features, but several other important factors remain, and these will now be considered.

Power

Sufficient power should be available to enable tungsten carbide tools to give of their best. It is only true that carbide tools absorb more power because they remove metal at a higher rate. It obviously requires power to separate the chips from the workpiece, and the more material we remove in a given time, the greater the power absorbed. The power consumed *per component* need not necessarily be higher.

It was shown earlier that by reducing the tool nose radius the absorbed power can be lessened. Similarly, less power is absorbed by tools with greater approach angles. Again, it was explained how, in the case of negative rake tools, the power required could be lessened by utilising secondary positive rakes to lessen chip friction. When such points are adopted, it is logical that in the interests of production the power thereby made available should be applied more usefully—in increasing the metal removal rate. This is most conveniently achieved by increasing the depth of cut, since the other factors, feed and speed, are less variable in a given case than is the depth of cut, as will be explained later.

The power required to secure a certain rate of metal removal with carbide tools can readily be derived from the Table of metal removal efficiencies (Table 1), which gives the average number of horsepower required to remove one cubic inch of the material in one minute. The way in which this Table should be used in practice, is to determine what horsepower is available *at the chuck*, select a speed and feed in accordance with the tool manufacturer's recommendations for the material being cut and the finish required, and hence calculate the maximum permissible depth of cut using the appropriate metal removal efficiency figure.

For example, we wish to turn the tread of a high quality solid carriage and wagon wheel, from 0.7% carbon steel forgings, on a vertical boring and turning mill having a 25 h.p. motor. Probably 4 h.p. will be absorbed in transmission losses, leaving about 21 h.p. available at the chuck. For roughing 55 tons per

Table 1. RELATIVE MACHINABILITY OF ENGINEERING MATERIALS

Material and condition	cu. ins./h.p/min.
Aluminium alloys	6.0
Copper	3.0
Cupro-nickel	2.0
Soft brass	1.5
Cast iron (200 Brinell)	1.25
1 per cent. nickel iron castings	1.25
Spun-cast iron	1.25
Malleable iron (low steel content)	1.25
Cast brass	1.2
Phosphor bronze	1.15
Aluminium bronze	1.13
Manganese bronze	1.01
10 per cent. nickel iron castings	1.0
Malleable iron (high steel content)	0.9
0.3 to 0.4 per cent. carbon steel bars and forgings	0.85
0.7 per cent. carbon steel bars and forgings	0.72
0.3 to 0.4 per cent. carbon steel castings	0.70
Normalised 1 per cent. chrome manganese steel	0.70
55 tons tensile 1 per cent. chrome steel	0.70
65 to 75 tons tensile nickel chrome steel	0.65
3 per cent. nickel steel	0.6
100 tons tensile nickel chrome steel	0.6
Stainless steel bars and forgings	0.5
Stainless steel castings	0.4

Table 2. TURNING SPEEDS WITH STEEL-CUTTING CARBIDE GRADES ON VARIOUS STEELS

f.p.m.	hard grades	average grades	tough grades
1000	-finish 0.15% Carbon bars		
900	-finish 0.35% Carbon bars	-finish 0.15% Carbon bars	
800	-rough 0.15% Carbon bars	-finish 0.35% Carbon bars	
700	-rough 0.35% Carbon bars		
600		-rough 0.15% Carbon bars	
500	-finish 55-70T alloy bars	-rough 0.35% Carbon bars	
400	-rough 55T alloy bars -finish 0.35% C castings -finish 3% nickel steel -finish 0.7% Carbon bars -rough 65-70T alloy bars -rough 0.35% C castings -rough 3% nickel steel	-finish 55-70T alloy bars -finish 0.35% C castings -finish 3% nickel steel -rough 55T alloy bars -finish 0.7% Carbon bars	
300	-rough 0.7% Carbon bars -finish 100T alloy bars -rough 100T alloy bars	-rough 65-75T alloy bars -rough 0.35% C castings -rough 3% nickel steel -rough 0.7% Carbon bars	-finish 0.15-4% C castings and bars
200		-finish 100T alloy bars -rough 100T alloy bars	-rough 0.15-4% C castings and bars -finish 55T alloy bars
100			-rough 55T alloy bars -finish 0.7% Carbon bars -rough 0.7% Carbon bars
0			

N.B. :—The speeds for machining forgings are the same as for bars, but speeds for machining castings are generally somewhat lower.

square inch forgings, we will employ 200 feet per minute (19 revs. per minute on 40 inch tread diameter) with a .028 inch per revolution feed. The actual rate of metal removal in cubic inches per minute will be 40 x 3.1416 x 19 x .028 x depth of cut; in other words 67 x maximum depth of cut.

Now, our metal removal efficiency for 0.7% carbon steel is 0.72 cubic inches per horsepower per minute, from Table 1, which is 15 cubic inches per minute, from 21 horsepower. Thus 67 x maximum depth of cut = 15, whence the maximum depth of cut is .22, or say 3/16 inch to allow for approximations. This depth of cut should be used as making the most effective use of the available horse-power. With double the power, the depth of cut could in fact be doubled provided that the chucking were adequate and the part itself strong enough to withstand the power it transmits.

Table 3. RANGES OF TURNING SPEEDS WITH STRAIGHT-GRADE CARBIDES ON IRONS AND NON-FERROUS MATERIALS

If, after such calculation, the computed depth of cut stalls the machine, the cause will almost certainly be slack driving belts or maladjusted clutches, and these matters should be put right on all machine tools before using any carbide at all.

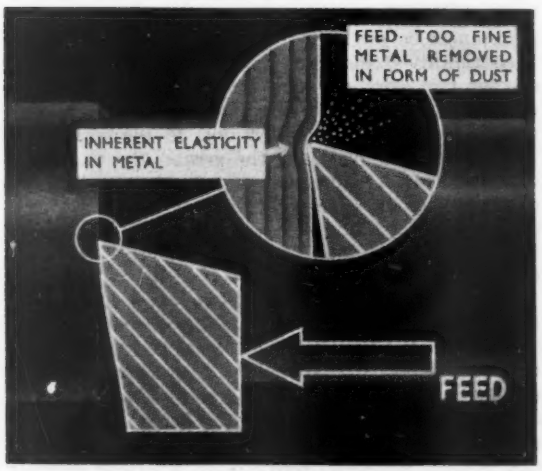


Fig. 28

Speeds and Feeds

Every material has its optimum cutting speed—namely that at which the tool life and metal removal rate are a maximum. The usually suggested procedure for arriving at this optimum cutting speed is to take a series of trial cuts at different speeds, the lowest speed at which a marked improvement in finish occurs being the most satisfactory for normal machining. Finishing cuts, which generally impose lower cutting pressures since both feed and depth of cut are much lower, can be taken at the maximum speed recommended by the tool manufacturers. Some recommended turning speeds for tungsten carbide tipped tools are listed in Tables 2 and 3. Each material can generally be machined at two or three different speeds, depending on the hardness of the grade used to machine it. This, in turn, depends on job and machine conditions. The hardest grade will naturally be capable of the highest cutting speed, and will possess the longest tool life, but hard grades will fail prematurely unless the machine, the tool and the work are rigid.

At the other end of the scale, the softer cutting grades will have a lower metal removal rate, and usually a lower tool life, but they will be tougher, and therefore suited to roughing forgings, or for interrupted cuts, or for work which is not rigid. The

mean of these is an average grade for the material. Usually, each manufacturer's grades can be identified as classifiable as 'hard', 'average' or 'tough', from the various manufacturers' tables of their own grade applications.

It should be borne in mind that Tables 2 and 3 give average figures which local circumstances and conditions are likely to vary either up or down, and the Tables should also be used with regard to the economic considerations of time per component and components per regrind. Boring speeds are about two thirds of turning speeds, due to the fact that boring tools are almost invariably less rigid than turning tools, whilst milling speeds are practically the same as turning speeds.

Feeds are a matter on which recommendations are impracticable, the factors affecting the choice of feed being the finish desired, the power available, the rigidity of the tool and the work, and the material being machined. A warning against too fine a feed must be given. Very fine feeds, below the amount of indentation which all materials will withstand, due to elastic deformation, before permitting actual tool penetration, will result merely in rubbing. The metal does not come away in chips, but in the form of dust (Fig. 28) and this will damage the front clearance of the tool, where all wear starts. If the nature of the cutting operation demands fine feeds, such as in jig boring for example, a keenly lapped cutting edge is recommended, so that even at fine feeds, a proper chip is produced. Perhaps the safest generalisation is that a feed capable of producing a good healthy chip should be aimed at, too coarse a feed on the other hand being evidenced generally by chipping of the cutting edge.

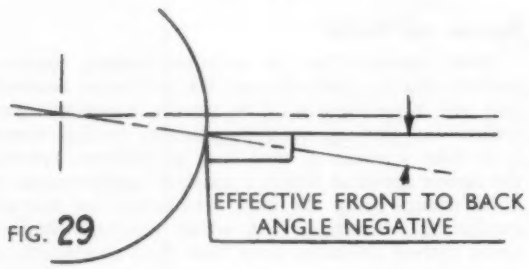


FIG. 29

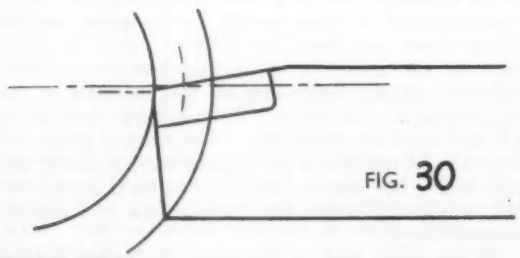


FIG. 30

Tool Setting

The effect on front to back angle, and on front clearance, of the use of rocker (or boat type) tool posts, should be appreciated, and such tool posts replaced so that the tool base is always horizontal (in the case of normal cantilever tools). The front to back and clearance angles will then be unaltered if the tool is on centre.

Positive rake tools should be on centre, unless it is desired to provide a virtual or effective negative front to back angle without grinding, on positive rake or zero rake tools. (Fig. 29). This principle does help to overcome difficult jobs such as iron castings with excessive inclusions or blow-holes, as the effective negative rake protects the extreme cutting edge in exactly the same way as shown earlier in Fig. 17, although the practice should be employed with caution, as setting the tool below centre also increases the effective front clearance and this, therefore, gives less support to the cutting edge. In the case of boring tools, opposite effects occur, the tool requiring to be set slightly above centre to secure effective negative rake, or to reduce existing positive rakes.

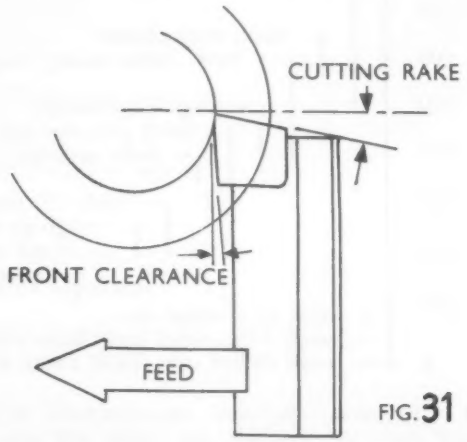


FIG. 31

Tools with negative front to back angles should invariably have the tool point set below centre, as shown in Fig. 30, so that the mean point of the depth of cut is **on** centre. Except in the case of boring tools, carbide tools should never in any circumstances be used above centre.

As rigidity is the most important consideration in carbide tool work, it should become a habit with the operator to clamp the tool very firmly, and to reduce the overhang (in both directions) to the minimum. The greater the overhang, the greater the tool point deflexion (in fact the deflexion increases as the cube of the overhang—i.e. is eight times as much for 1 inch overhang as for 0.5 inch overhang). The greater the tool point deflexion, the greater the tool wear and the shorter the tool life.

For extreme rigidity, such as is required for wide forming cuts, or high speed roughing of shell forgings, for example, the tool is frequently applied tangentially to the work in a suitable holder, as shown in Fig. 31, the greater thrust thus being almost along the tool axis, and the tool tip deflexion being exceedingly small. Tangential tooling is particularly useful in the case of deep grooving, which is an otherwise difficult operation.

Many cases of premature tool failure are traceable to bad tool setting, and expensive tools (and, on occasion the work itself) can be saved by attention to these points at the outset.

Tip Grades

It is perhaps unfortunate that most carbides will cut most materials—after a fashion—without the question of grades ever being considered. It is just as absurd to use the wrong grade of carbide for a particular application, as it is for example to make spanners out of cast iron ; they will do the job in many cases, but premature failure is certain.

In the first Paper, in which the manufacture of tungsten carbide was described, it was explained how all the grades fell into two broad classifications. Carbides for cutting cast-iron, non-ferrous metals and, in fact, materials which do not form continuous chips, were shown to be tungsten carbide-cobalt alloys, and these were called the straight grades. The remaining cutting grades, used for steels of various hardnesses, and such materials that form continuous chips, were shown to be tungsten carbide-titanium carbide-cobalt alloys. This distinction is fundamental and vital. The addition of titanium carbide was explained as being necessary to prevent the phenomenon of the built-up cutting edge, which was observed when the first sintered carbides ever produced (which were straight grades) were used for machining steel.

Within these two broad classifications, the grades then differ in their hardness, which is varied by the amount of cobalt they contain or, in some cases, by the grain size of the powders of which the tip is composed. Naturally, we wish to use the hardest grade practicable, since then our tool life will be highest. But the harder grades are less shock resistant, and for roughing, or machining castings with blow-holes and inclusions, or forgings, or interrupted work, we must apply tougher grades containing more cobalt, which are correspondingly softer.

In order to emphasise the existence of grades more fully, a Table is included which gives comparisons of the principal cutting grades of some of the makes of carbide in common use (Table 4). These are approximate as small differences between alternative grades exist. These are deliberate, to achieve particular characteristics, but they prevent a direct comparison.

TOOL RESERVICING

When to Reservice

With reservicing the prime question is—'When to reservice ?' If a tool (or a cutter) is reserviced at the right time, maximum ultimate tool life is ensured, as it is then necessary to remove very little carbide to restore the tool to as-new condition. Wear invariably originates on the front clearance, and the front clearance, just below the cutting edge, should be watched as an indication of when to reservice. When this clearance is dulled for about .03 inch, the tool should be removed, for reconditioning at this stage involves only lapping with a diamond impregnated wheel, and is the work of a few moments. Tools which are allowed to continue cutting (or rubbing) after the described amount of wear has taken place, consume greater horse-power, generate more heat, and reach the stage where excessive amounts of carbide must be ground away in resharpening.

Table 4. COMPARISON OF SOME MANUFACTURERS' MACHINING GRADES

Applications :

1. Cast iron and non-ferrous metal or abrasive material finishing (hard grades).
2. Cast iron and non-ferrous metal general purpose machining (average grades).
3. Cast iron and non-ferrous metal interrupted cutting and heavy roughing (tough grades).
4. Steel finishing and machining at high speeds and fine feeds (hard grades).
5. Steel general purpose machining (average grades).
6. Steel interrupted cutting and heavy roughing (tough grades).
7. Light alloy machining.

Applications (see above) ⟶		1	2	3	4	5	6	7
ARDOLOGY	(Alfred Herbert/B.T.H.)	1A/179	1A/179	2A	S200	S200	S48	1A/179
BALFALLOY	(Arthur Balfour)	H	FS	HL	HA	Z	HD	FS
CARBOLOY	(Carboloy Corp., U.S.A.)	905	883	44A	78	78B	78C	883
CONTINENTAL EUROPEAN GRADES		H1	G1	G2	S1	S2	S3	—
CUTANIT	(Jessop/Metro-Vickers)	ICC	I	M	S	T	R	ICC
KENNAMETAL	(Kennametal, U.S.A.)	K6	K6	K2S	K4H	K3H	KM	K4H K6
MITIA	(Firth-Brown)	C	B	A	TC	TTA	TA5	B C
PROLITE	(Protolite/Murex)	21A 1C	15A	3R	6W	8K 14K	2W	8K 21A
WIDIA	(Fredk. Krupp, Germany)	H1	G1	G2	AT	TT1 TT2	TT3	—
WIMET	(Wickman)	H	N	N G	XX	X8	S58	X8

Wheels, Laps and Methods

Ordinary aluminium oxide wheels such as are used for grinding HSS tools are not suitable for grinding tungsten carbide. Silicon carbide wheels, known as green grit wheels, having harder cutting particles, are necessary. These are manufactured in India. In view of the extreme hardness of tungsten carbide, soft-bond wheels have to be employed, in accordance with usual grinding practice.

Fig. 32
Offhand grinding on a green grit wheel.

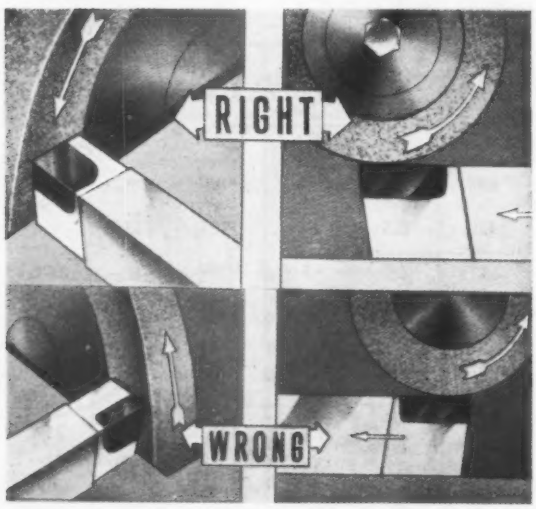


Fig. 33

Wheels of 60 to 80 grit, hardness symbol K, are normal for roughing, with somewhat harder wheels of 120 grit, say 120G, for finishing. The larger the wheel the greater the economy and efficiency, and 14-inch diameter wheels of 3-inch face are recommended for most purposes. If all the tools in use are below 1 inch however, an 8-inch diameter wheel could be employed. The wheels should run at a peripheral speed of 5,000 feet per minute, and it should be borne in mind that slower running wheels will appear softer, and will be used more rapidly.

For extensive reconditioning, rough grind the cutting rake and front to back angle (top of the tip) first. This face should be ground on the face of the wheel, not on the periphery. Peripheral offhand grinding produces a hollow ground effect which weakens the cutting edge. A slight camber should be dressed on the faces of the wheel, to keep the contact area, and hence heat generation, to a mimimum. To the same end the lightest possible pressures should be used, and the tool moved across the face of the wheel during grinding.

The side and end clearances on the shank, which are about 3° greater than the tip clearances, should then be ground on an aluminium oxide wheel, so that the clearances on the tip may subsequently be finish ground on the silicon carbide wheel without loading it with shank steel. The side clearance is ground next as shown in Fig. 32 and the front clearance (end of the tool) is ground last. All grinding must be on to the tip or into the cutting edge, as shown in Fig. 33, not off it, as otherwise unsupported grains of carbide would tend to be carried off the cutting edge. Grinding should preferably be carried out wet, with a copious volume of coolant to carry away excessive heat. If only a trickle of coolant or an intermittent flow is available, then the coolant should be completely turned off and the carbide ground dry. Heat alone cannot harm a carbide tool, but sudden and localised changes of temperature, such as arise from an interrupted coolant flow, can cause minute thermal cracks which ultimately bring about tip disintegration. Incidentally, this applies during actual cutting with coolants, also. The only drawback to dry grinding is that the tool becomes too hot for comfortable manipulation. When this occurs, it should be laid temporarily on one side, and another tool proceeded with. A carbide tool should NEVER be quenched. Although no visible effect may be apparent, minute cracks invisible to the naked eye would be likely to be caused by the thermal shock of quenching, and these cracks would cause splintering of the carbide in service.

For best results, particularly in terms of tool life, it is strongly advised that diamond lapping follows grinding. Diamond lapping is a standard operation at the time of manufacture and, in fact, if reservicing is not left until too late, it is frequently practicable to eliminate grinding, and to reservice by lapping only. The wheel may be a diamond impregnated resin bonded wheel, or a diamond impregnated metal bonded wheel. The latter are virtually indestructible, and are more suited to offhand lapping,

during which process the wheel comes in for rough treatment. Resin bonded wheels can relatively easily be abused, and are thus better suited to machine lapping where controlled pressures are possible. However, resin bonded wheels are freer cutting and faster in stock removal ability, and are probably more commonly used on account of this, and additionally they are cheaper. This is more than offset by the higher life of the metal bonded wheel, however, which is capable of relapping 22,000 tools, correctly used.

A machine lapping operation is shown in Fig. 21, which illustrates a 10-inch inserted blade face milling cutter being reserviced on the bevel angle clearance with a diamond impregnated resin bonded taper cup wheel.

The use of coolant is essential in lapping. Resin bonded wheels require very little coolant, a thin oil such as spindle oil being satisfactory, and just sufficient as is supplied by an oil-soaked felt wick in contact with the wheel, as shown in Fig. 21, is ample. Metal bonded wheels, on the other hand, require a copious flow of coolant, preferably water or water plus soda.

The cutting speeds required are not less than 5,000 surface feet per minute for resin bonded wheels, 6,500 s.f.p.m. being a maximum optimum, whilst metal bonded wheels should operate between 5,000 and 6,000 s.f.p.m. Diamond lapping by either wheel produces a greatly improved cutting edge which, in turn, at least doubles the tool life between reservicings in most cases.

Subsequent to diamond lapping, it is a common practice to stone lightly across the sharp corner of the extreme cutting edge, between the top and front faces of the tip, and to stone a slight strengthening nose radius on the tip, with a fine carborundum stick or, preferably, a diamond hand lap. This further increases edge life when machining steel, particularly if heavy or interrupted cuts are to be encountered.

Need to Abandon HSS Ideas

As in almost every aspect of tungsten carbide tooling technique, it is once again necessary to give the warning that HSS practice must be forgotten when using carbide. A cutting lip and hollow grinding, both common practice in HSS procedure, lead to a seriously weakened cutting edge which will therefore fail in service. These two points, together with the practice of quenching hot tools, are probably the most common in HSS grinding, and they must never be adopted when grinding tungsten carbide.

CARBIDE AT WORK

In this final section I wish to show a small selection of examples of tungsten carbide at work. Shortage of time prevents an exhaustive survey, but a brief look at the remaining illustrations will indicate some of the many ways in which tungsten carbide can assist production.

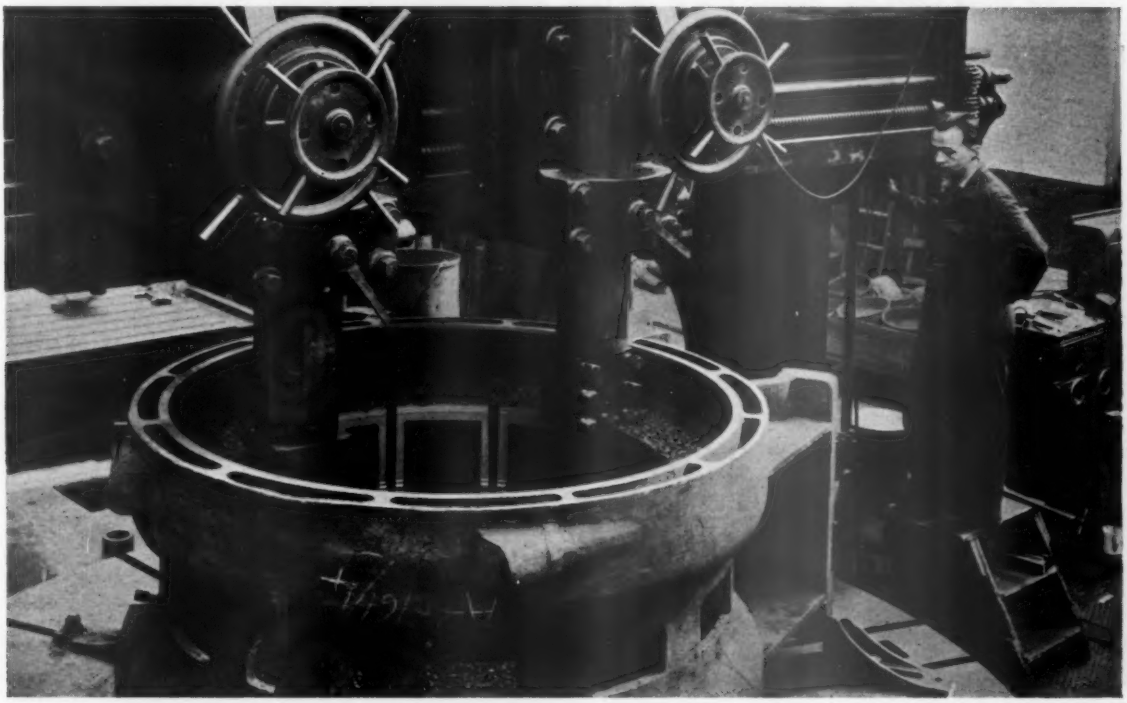


Fig.34

Interrupted cut vertical boring of a cast-iron stator casing at 160 f.p.m., .031 inch feed, up to 0.4 depth of cut.

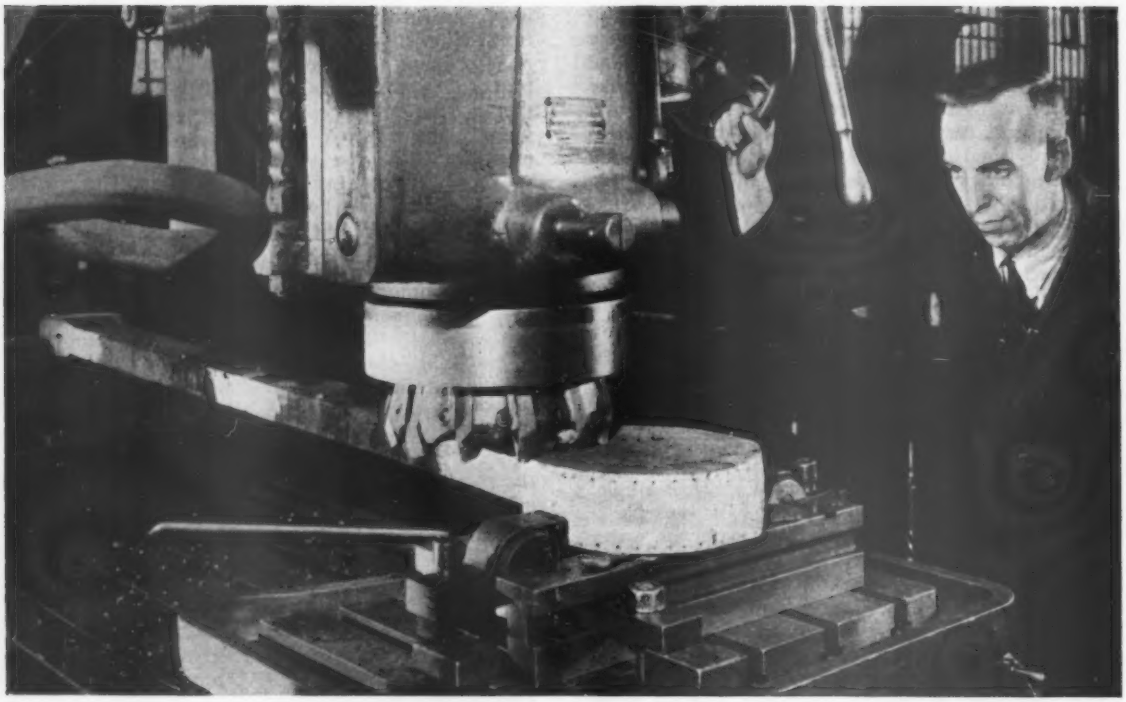


Fig. 35
Face milling forged steel eccentric rods at 720 f.p.m., 8.13 ins. per min. feed, up to 5/16 inch depth of cut.

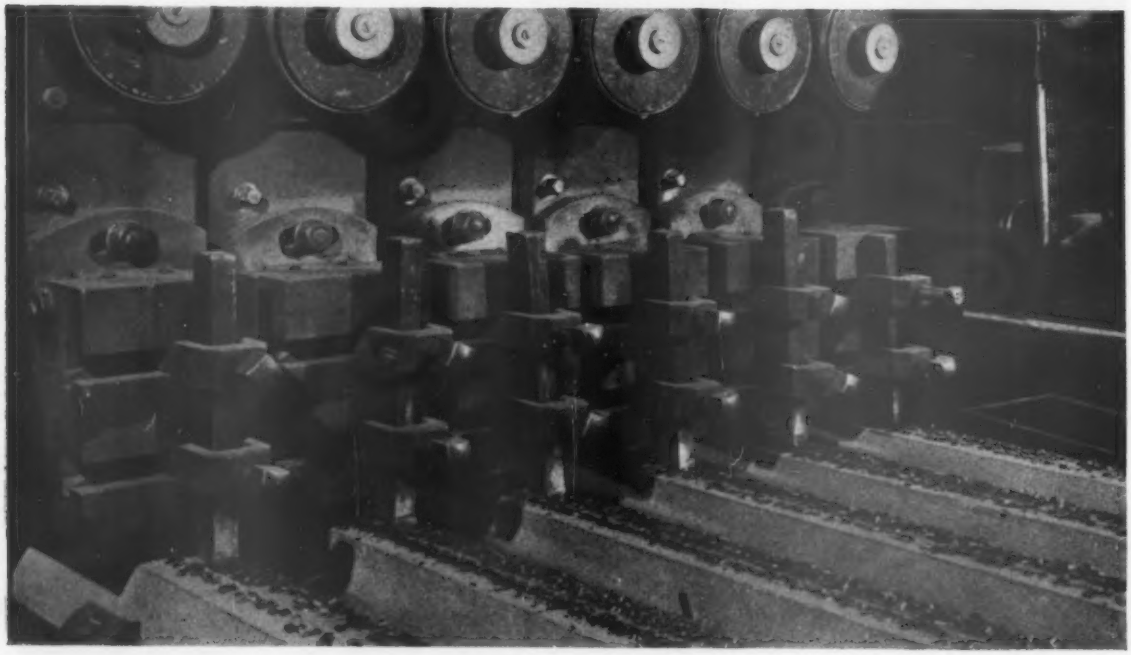


Fig. 36
Planing cast-iron roller beams at 100 f.p.m., 1/32 inch feed, 3/8 inch depth of cut, with a tool life between regrinds of 24 faces each 4 inches wide and 120 inches long.

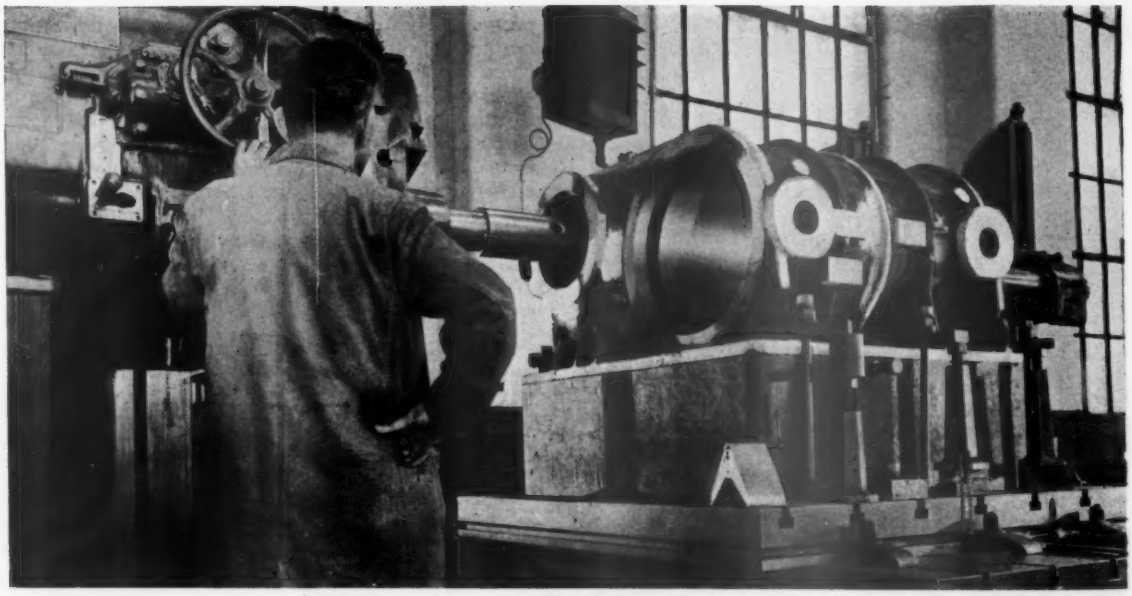


Fig. 37
Close tolerance horizontal boring of a cast-iron steam chest at 242 f.p.m., .020 inch feed, up to 3/8 inch depth of cut, with the 21 inch diameter bore held to .00025 inch over its 40 inch length.

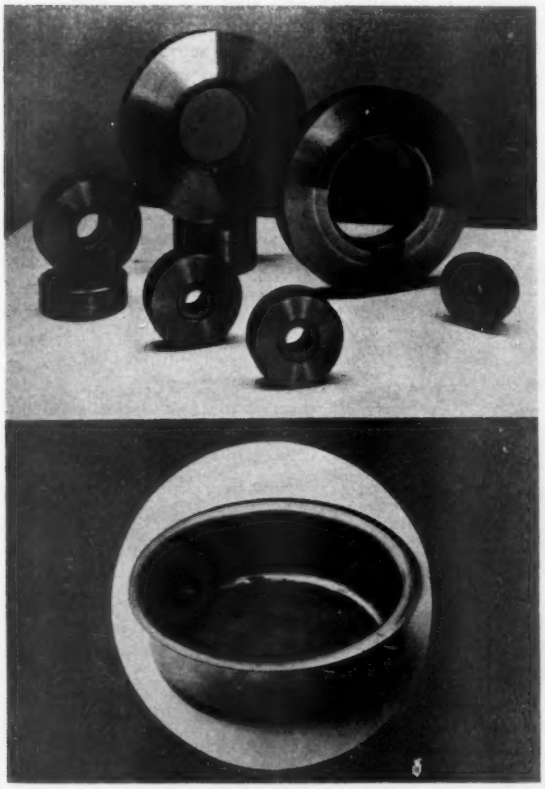


Fig. 38
Tube drawing dies and round hollow-ware dies with carbide rings.

Machining

First of all, machining applications. Fig. 34 shows a rigorous application, vertical boring with a severely interrupted cut. The job is an 80-inch diameter cast iron stator casing, having twelve dovetail slots 2-inches wide in the bore. Boring is at 160 feet per minute, .031 inches feed, 0.3 to 0.4 inch depth of cut. A wide approach angle allows the tool to withstand the 14,000 impacts sustained during the operation.

Fig. 35 shows a carbide milling cutter at work, face milling forged steel eccentric rods on a Herbert 28 V Milling Machine. The component is 6 feet long, with bosses 9½ and 5½ inches diameter, the material being of 30-35 tons tensile. A 12-inch diameter twelve blade milling cutter is used, with negative helix angle and negative radial rake, at 230 revs. per min. (720 feet per min.) and a feed of 8.13 inches per min. The depth of cut varies from ¼ inch to 5/16 inch. The rods are produced in batches of ten, each having four milled faces. The cutter does not require re-lapping during the batch, forty faces per re-lap being produced.

Planing and shaping steel and cast iron are well within the capabilities of tungsten carbide, provided that some form of tool lifter is employed to prevent the tip being dragged backwards over the work. Fig. 36 shows a multi-tool planing cut on cast-iron roller beams on a special twin-bed Butler planer with six tool boxes. The beams are planed on four faces at 100 feet per minute with 3/8 inch depth of cut, employing 1/32 inch feed. The tool life between re-grinds is 6 beams (24 faces four inches wide) each 10 feet long.

The final illustration under the sub-heading of machining (and those illustrated are orthodox

Fig. 39
Segmental carbide die producing automatic razor boxes.

everyday jobs) shows a straightforward horizontal boring job on a cast iron locomotive steam chest (Fig. 37). The notable feature here is the close tolerance held by the tool. The larger bore is 21 inches diameter, 40 inches long, and over this length is held to .00025 inch. Moreover, four cylinders (eight bores including the 13-inch bores) are bored per regrind. This performance is secured at a cutting speed of 44 revs. per minute for the larger bore (242 feet per minute) with a .020 inch per rev. feed, depth of cut varying from 5/16 inch to 3/8 inch.

Other Applications

Apart from machining, however, there is wide scope for the employment of tungsten carbide in other ways. Fig. 38 shows carbide tube drawing dies and round hollow-ware dies. Such dies possess amazing life, one example being a drawing die for producing kettle bases, which has produced four million pieces without measurable die wear.

Fig. 39 shows a segmental die in use, producing boxes for automatic razors. The die shown has outlasted 20 steel tools with no sign of wear, and is still in use. Quite apart from considerable direct tool cost saving, this particular application also eliminated over 50% of the normal subsequent polishing operations.

Another press tool application, which shows vast saving, is to punches and dies for razor blades, for which the unassembled solid and carbide tipped punches and solid carbide die segments are shown in Fig. 40. Production between regrinds compared with the best previous performance from steel dies, was fifteen times greater, 3,000,000 blades per regrind

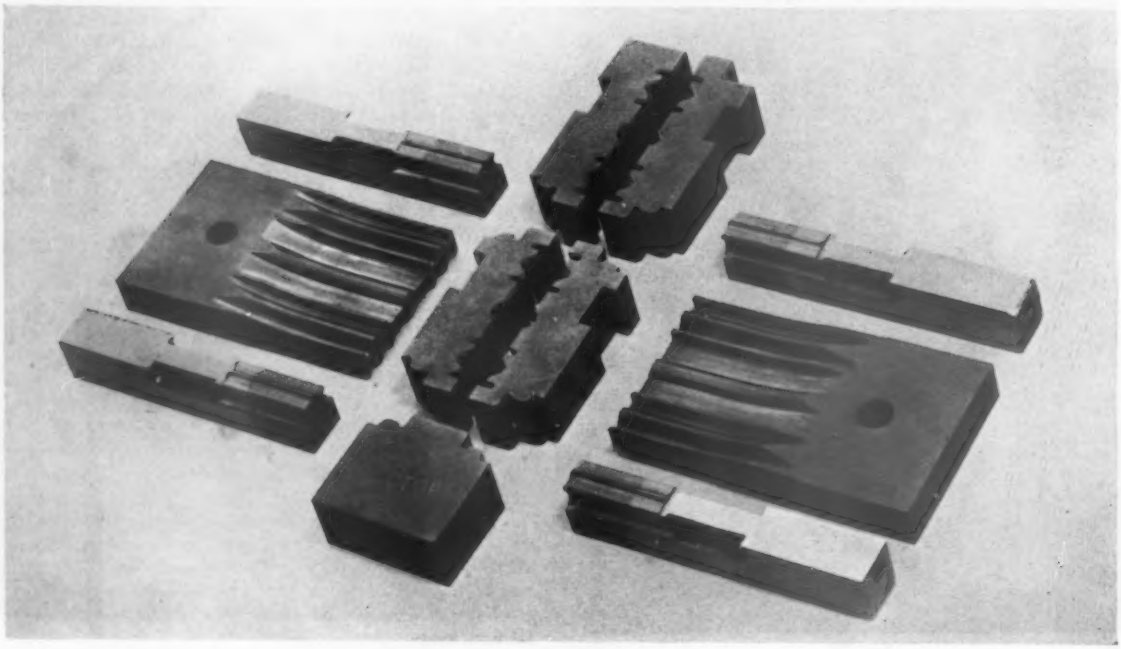


Fig. 40
Solid and tipped carbide punches and solid carbide die segments of a razor blade press tool set.

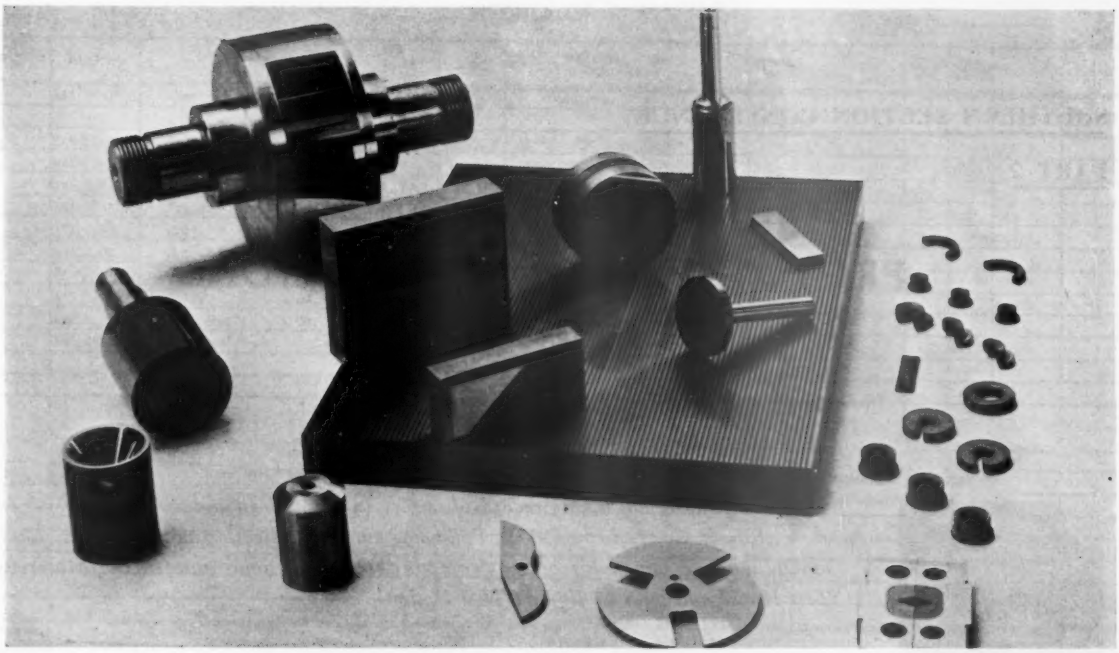


Fig. 41
Tungsten carbide wear-resistant parts for a variety of manufacturing industries.

being produced, (two per stroke). The total life has not yet been assessed, but as only .002/.003 inch of carbide is removed during regrinding, the ultimate life should be about 75 times the life of steel dies.

Finally, a selection of wear resistant carbide parts. The range shown in Fig. 41 includes plug gauge members, micrometer anvils, a strip sizing roll, steady bushes for Swiss-type autos, a split die for zip-fastener tooling, wear resistant machine parts, and thread guides for textile machinery. The centrepiece is a solid carbide comparator base which is ground and lapped optically flat. The life of this plate will never be measured.

Conclusion

It has been described and illustrated how tungsten carbide should be used, and how, correctly used, it can raise metal removal rates, raise productivity, and hence lower costs. It can do so and, in fact, is doing so in thousands of factories, on ordinary readily available everyday machines, in no sense designed for carbide. This fact has been shown in the machining illustrations in this paper.

On most machine tools in virtually every industry improved tool life, sustained accuracy, and increased productivity compared with other metalworking methods, can immediately result from the correct utilisation of tungsten carbide, and a widening range of applications is being found to exploit the capabilities of this remarkable material.

In fact, it is probably true to say that without tungsten carbide, production, as we understand the term today, would be impossible.

Acknowledgments

All illustrations and tables except figures 1, 2, 3, 6, 7, 8, 15, 16, 17, 29 *and* 31 *are by courtesy of Wickman Limited, Coventry, England.*

In addition, the author is indebted to Wickman Limited and the following firms, for certain photographs:

Figure 34 — *Lancashire Dynamo and Crypto Co. Ltd., Manchester*

Figure 35 — *British Railways (London Midland Region)*

Figure 36 — *Howard and Bullough Ltd., Accrington*

Figure 37 — *British Railways (London Midland Region)*

Figure 39 — *Wilkinson Sword Co. Ltd., London*

Figure 41 — *Taylor, Taylor and Hobson Ltd., Leicester (inter alia)*

The names of proprietary carbides tabulated in the paper, also the names Easy-flo, Sifbronze and Sif-flux, are registered trade marks.

SOUTHERN SECTION CONFERENCE

PART 2

PROTOTYPE TO PRODUCTION

PART 1

by C. E. FIELDING, O.B.E. A.F.R.Ae.S. M.I.Prod.E.

Mr. C. E. Fielding

Mr. Fielding has a long record of service in the aircraft industry, having joined A. V. Roe & Co. Ltd., in 1917. Following an apprenticeship with T. & R. Lees, of Oldham, he joined his present company, spending some time in the Materials Test House and later in Jig and Tool Design.

In 1921, he was appointed Chief Inspector and six years later became Assistant Works Manager, visiting the U.S.A. in 1929 as Technical Adviser to firms manufacturing AVRO aircraft.

In 1937, he became Assistant General Manager and was appointed to his present position of Works Director in 1943.

THE Paper which I have prepared on this subject will deal with the forward planning and control necessary to guide a new aircraft through its various phases, right up to the completion of the first aircraft. I do not believe that it is possible to exaggerate the importance of this aspect of production, as much time can be saved and the job made to run more smoothly by proper organisation and planning at the very beginning of the contract and during its life.

I shall assume that the prototype has cleared its trials and that production drawings are available, or alternatively, that a realistic programme for the issue of drawings has been agreed with the Design Office.

The contract, besides giving the quantity, includes the delivery programme and, armed with this information, the activities of several departments start concurrently. These can be divided into the following main groups :—

Group 1. Preparation of Piece-Part Schedules and Bulk Material Schedules for ordering purposes.

Group 2. Establishment of Process Planning and Tooling arrangements.

Group 3. Preparation of Target Programmes and analysis of capacity in relation to Machine Tools, Floor Space and Labour.

The above groups can be termed the "how", "when" and "where" departments, as distinct from the "do" department, which is production, the reason being that they settle how the aircraft is to be built, when it is to be built and where it is to be built. I cannot stress too strongly the care and attention which is necessary in preparing these plans, as decisions made and action taken in the early stages of a contract have a most important bearing on the successful completion of a production programme. Time lost in carrying this out can never be fully recovered.

Piece-Part Scheduling and Material Ordering

It does not require me to remind anyone how important it is to place the orders for materials as quickly as possible, but what I would like to emphasise is that this can be speeded up if the right type of paperwork is used.

The Design Office have to issue a Schedule of Parts with each drawing, and it is important that this

D/1. = 2A

SCHEDULE OF PARTS

Works Order No:-
Contract No:-

WEIGHT	PART Nº	DESCRIPTION	Nº OFF PER UNIT	SPEC.	MATERIAL SIZE PER PART	ACTION BY	MATERIAL REQUIRED FOR 100 PARTS	Total No. Off this Stage	Total Contract Quantity		
	EA1-20-1255	Check Link Assy Port.	1		Complete.	P		1			
	EA1-20-1253	Check Link.	1	DTD.683	2½" x 7/8" Rect. x 5½" lg.	P	43.75 ft.		26.75	C65/1	
	EA1-20-1311	Finger.	1	L.40	1" x 3/8" Rect x 2 3/8" lg.	P	20.00 ft.		10.00	C65/1	
	A16.YJT.	Nut. 3/8" B.S.F.	1			BO.				C65/3.	
	EA1-20-1289	Tappet	1	S.1	½" Dia x 1" lg.	P	8.50 ft.		4.25	C65/1.	
	A15.Z.7C.	Bolt. 2 BA.	1			BO.				C65/3.	
	A16.Z.CP.	Nut. 2 BA.	1			BO.				C65/3.	
	EA1-20-1265	Check Link.	1	DTD.683	2" x 5/8" Rect x 5½" lg.	P	48.00 ft.		24.00	C65/2.	
	A15.Y.15B.	Bolt. 4 BA.	3			BO				C65/4.	
	A16.Y.BT.	Thin Nut 4 BA.	3			BO.				C65/4.	
	EA1-20-2927	Distance Piece.	1	DTD.683	1½" x 1¼" Rect x 2" lg = 2 off	P.	8.50 ft.		4.25	C65/2	

INFORMATION SUPPLIED BY DRAWING OFFICE — INFORMATION EXTENDED BY BY SCHEDULE CLERK

REMARKS

ISSUE Nº	1	USED ON EA1-20-10733	STAGE EA3-00-1	TYPE Canberra Mk.2	
MOD. Nº	10396	TITLE	Nº OF SHTS. 1	SHT. Nº 1	
DATE	25.1.62	Check Link Assy. Port	SCHED. Nº EA1-20-1255		72
DRAWN	T.Ford.				

Fig. 1

schedule should be made out in the order most suitable to the shops, to avoid the duplication of effort involved in any re-writing or re-grouping by the Schedule Clerk.

Fig. 1 shows a typical schedule of a small sub-assembly, as issued by the Design Office, giving the Part Number, Description, Number Off Per Unit, Material Specification and Material Size Per Part. The Schedule Clerk has then only to extend this information in the columns provided for him and these specify the source of manufacture, whether it is in your own shops, sub-contract or bought-out: the material required per stage; and the total material quantity for the contract.

Fig. 2 shows the Posting Sheet, which gives the material information from the Piece-Part Schedule and collects all similar material together to give a bulk quantity. The Bulk Material Schedule is really a collection of material from these Posting Sheets and is the basis of the demands put through to Buying Department for purchasing.

During the time that the Schedule Clerk is arranging for the ordering of materials, the Planning Section make a review of items made from bar stock and if possible change the material to forgings, extrusions, etc. in order to save machine man hours. These are agreed with the Design Office and amendments made to drawings and schedules.

The Piece-Part Schedule is also used to establish

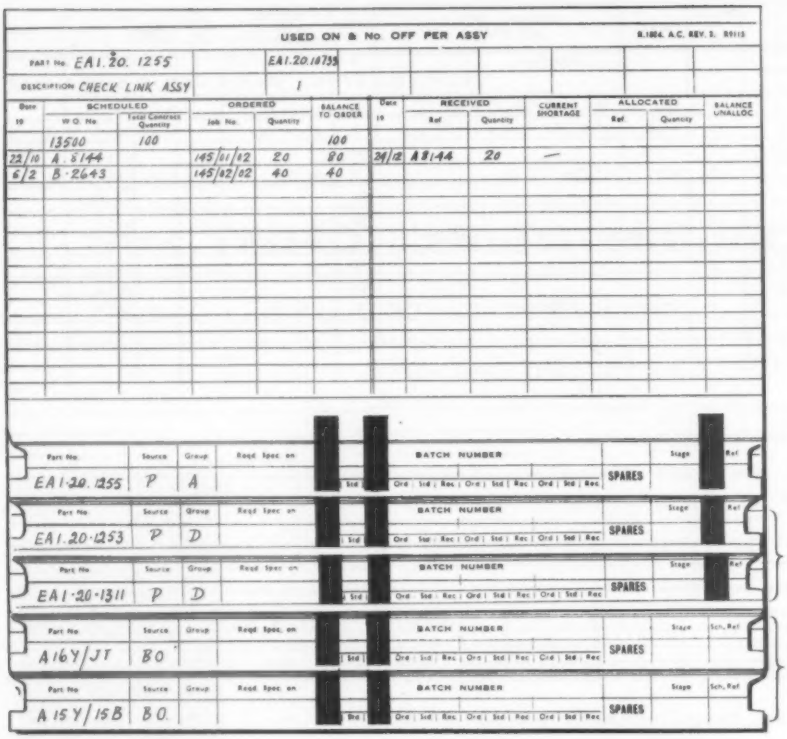
R.1814.REV. — w/o 785004 100 SETS — MATERIAL POSTING SHEET — C.65/1

REF.	QUANTITY ADDED	QUANTITY CANCELLED	BALANCE	REF.	QUANTITY ADDED	QUANTITY CANCELLED	BALANCE	REF.	QUANTITY ADDED	QUANTITY CANCELLED	BALANCE
ODT PAGE 9 EA1 20-125	43·75 FT		43·75 FT	ODT PAGE 9 EA1 20 131	20·00 FT		20·00 FT	ODT PAGE 9 EA1 20 1289	8·50 FT		8·50 FT
EA3 20 23		21·00 FT	22·75 FT	EA1 20 1313	15·25 FT		35·25 FT	EA1 20 1311	14·00 FT		22·50 FT
EA1 20 101	12·50 FT		35·25 FT	EA3 20 66	12·00 FT		47·25 FT	EA1 20 1323	7·25 FT		29·75 FT
EA1 20 121	34·00 FT		69·25 FT	EA3 20 67	16·50 FT		63·75 FT	EA1 20 1616	18·00 FT		47·75 FT
EA3 20 61	20·50 FT		89·75 FT	EA3 20 68	5·00 FT		68·75 FT	EA3 20 4	4·50 FT		52·25 FT
EA3 20 47	11·25 FT		101·00 FT					EA3 20 19	12·25 FT		64·50 FT
EA3 20 81	20·00 FT		121·00 FT					EA3 20 187	14·50 FT		79·00 FT
EA1 20 100	17·25 FT		138·25 FT								
EA1 20 114	10·00 FT		148·25 FT								
EA1 20 134	16·00 FT		164·25 FT								

MATERIAL	SPEC	SIZE
LIGHT ALLOY BAR	DTD 683	2½" x ⅞" RECT.
LIGHT ALLOY BAR	L.40	1" x ⅜" RECT
STEEL BAR	S.1	½" DIA.

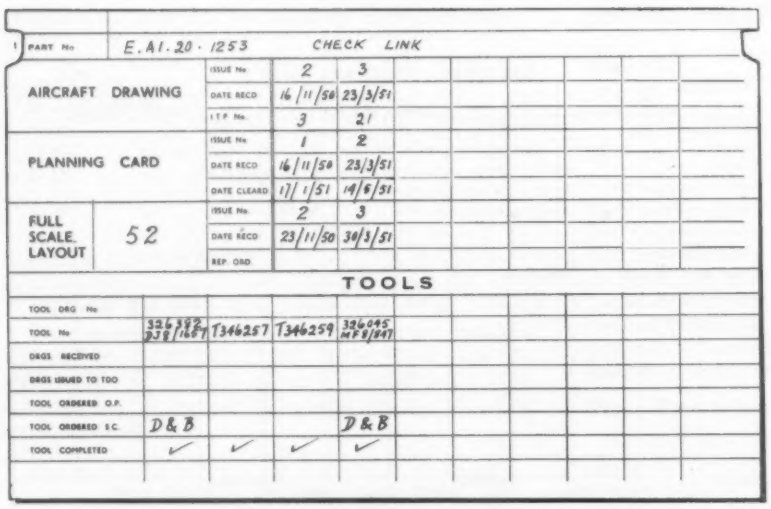
Fig. 2

CONTROL RECORD CARDS



FRONT VIEW

1. Assembly Card (pink); 2. Own Production Parts (white); 3. Bought Out Parts (green).



BACK VIEW

Fig. 3

the Control Record Cards, (Fig. 3). These Record Cards are arranged to show the pre-production information on one side and production position on the other, and the visible edge signals enable a quick and accurate assessment to be made of the position at any time.

A card is made out for every single item and sub-assembly and these are filed in the cabinets, first in component sequence and then in sub-assembly sequence with the components.

It will be seen that when this is completed it forms a very valuable master record of every item in the aircraft and with the visible edge signals, items which are lagging can be quickly spotted. This system of recording is also very flexible, in that it allows aircraft modifications and alterations to be introduced in the master record, in the proper sequence, without undue trouble.

The information from these records is summarised in the form of Weekly Reports, which are issued to the executives concerned.

Fig. 4 shows one of these Reports, which is so arranged to give the Drawing Schedule, and Process Planning position both weekly and accumulative, and allows checks to be made against the planned target programmes.

It will be realised how extremely valuable this is to an executive as it allows him to keep his finger on the pulse, check up the lagging departments and take corrective action where necessary and before it is too late.

Process Planning and Tooling

This is the "how" department, and engineers working in this section decide how the parts are to be made.

Fig. 5 shows a typical Process Sheet and it will be seen that every manufacturing operation is specified, special jigs and tools required are de-

PRE-PRODUCTION PROGRESS REPORT

WEEK NO. 36

		Design Office		Aircraft Control						Process Dept.	
		No. of Drawings Issued		No. of Drawings Scheduled		No. of Drawings Material Checked		No. of Items on Record Card		No. of Drawings Processed	
Stage	Description	Wkly.	Cum.	Wkly.	Cum.	Wkly.	Cum.	Wkly.	Cum.	Wkly.	Cum.
D1.	Front Fuselage.	22	188	-	166	-	118	-	472	7	132
D2.	Fuselage (Main).	31	380	10	357	23	308	52	805	3	282
D3.	Fuselage (Rear).	5	79	4	72	4	53	16	321	-	74
D5A6.	Bomb Door.	-	16	-	16	-	8	-	92	-	16
F1.	Centre Section.	96	1002	110	966	146	942	351	3992	120	806
F2A3.	Outer Wing.	124	1134	130	1027	93	971	290	4670	103	820
F4A5.	Wing Tip.	-	18	-	16	-	16	-	56	-	18
F6A7.	Ailerons.	6	34	-	22	-	18	-	101	-	28
G3A4.	Elevators.	16	90	6	73	4	52	18	273	17	62
G5.	Rudder.	3	52	-	30	-	-	-	166	-	50
G7.	Fin.	-	31	-	25	-	14	-	94	-	12
	TOTAL.	303	3024	260	2770	270	2500	727	11042	250	2300

Fig. 4

DWG. NO.	QUANT.	JOB NO.	DESCRIPTION	STAGE	FILE NO.		PROCESS SHEET
2.G.3317			Side Member				
DWG. NO. CHECK	MATERIAL		SPEC.	ALLOWANCE	RATE FIXER		
2.G.3317	Made from 165.SS.3075 7.3/8" long = 1 off		L.40.				
ISS. NO.	PROCESSED BY	DATE	FOLDER NO.	NO PER SET	USED ON	MAX NO. ISSUED	
2	L.E.	29.1.52	D2/0.	1.	1.0.3317		

DEPARTMENT	OP. NO.	OPERATION	TOOLS	FIXED PRICE	EST. PRICE
S.S.	A	Issue material in length to Wadkin Saw.			
W.K.S.	1.	Cut section to dead length 7.1/4" long			30 ph.
B.B.	2.	Dress			120 ph.
L.D.	3.	Drill complete to template.	T.289178		20 ph.
L.P.	4.	Profile to shape - note hand in relation to drilling.	T.289179		15 ph.
B.B.	5.	Dress			120 ph.
L.M.	6.	Finish mill 1/8" radius at one end			20 ph.
L.D.	7.	C'sk. two holes - note hand			60 ph.
I.D.	E.	Inspect			
P.S.	C.	Degrease and Anodise			120 ph.
P.S.	8.	One coat of Grey Primer DTD.517			

Fig. 5

cleared, and estimated times quoted. It is interesting to note that the master copy of this Process Sheet is used for producing the Job Cards, thus avoiding any errors in reproduction.

The methods of manufacture laid down by the Process Engineer vary according to the quantities to be produced and the type of plant available. The objective is to call for the simplest type of tool which will give a satisfactory job on the parts required, and this has the dual effect of reducing tooling costs and getting the tools made more quickly, thus saving valuable tooling hours.

I do not propose to go into detail regarding the various types of tools used, as the majority are pretty well universal in the aircraft industry and time will not allow me to do this. I would, however, like to refer to the development of new and special processes and to say how important it is to have a section in the factory responsible for these. Much of their work lies in keeping a close liaison with the Design Office in the very early stages of design, and a careful watch on its producibility. This cannot be emphasised too strongly, as unless action is taken early enough, it is usually too late to do anything about it.

This section also controls normal tooling development and supplies information to the Process Engineers for their guidance.

Interchangeability

I should also like to refer to interchangeability, as I consider that this should be discussed at the very start of the job, all interchangeability points agreed and any tools affecting this issue given priority. If this is done, it will save a lot of headaches and will certainly be a big help in production.

Until the interchangeability points have been carefully analysed, it is never obvious how far-reaching are the implications, or how many details and sub-assemblies must be controlled. If these details and sub-assemblies are made before these facts are realised, a lot of trouble is caused, whereas if they are known and realised in time, interchangeability becomes more of a blessing than a nightmare.

I would also like to stress the importance of getting out provisional estimates of the number of tools required to make the complete aircraft, so that a tooling programme can be prepared and necessary arrangements made to meet it. This can be done by careful analysis of representative parts of the aircraft and by comparison with the tool requirements from previous types of aircraft, thus permitting a sufficiently accurate estimate to be made to allow the tool programme to be prepared.

From this, target programmes are made out, both for the issuing of tools for manufacture and also for the manufacture of tools, and from that time onwards a weekly report is issued to the executives concerned. This information is extracted from the Control Record Card already referred to.

A typical Tool Report is seen in Fig. 6 which shows Tools demanded by Process Planning, Tools cleared by Jig and Tool Design Office, Tools issued for manufacture and Tools completed. This gives weekly as well as cumulative figures for checking against the tooling target programme.

At this early stage, the target can be set on the amount of sub-contracting which will be necessary, as the existing tool capacity is known and the difference between that and the target programme will have to be made up by sub-contracting.

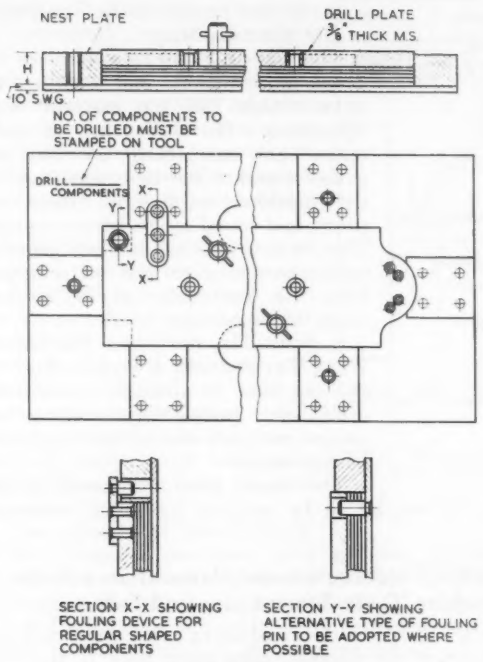
Tool arrangements can then be made early enough to have a reasonable chance of getting good service from the sub-contractors. The importance of this can hardly be overstated.

The issue and completion of tools at sub-contractors should also be the subject of Weekly Reports and I would point out the necessity of keeping a very close liaison in this direction, both technically and from the ordinary progressing angle.

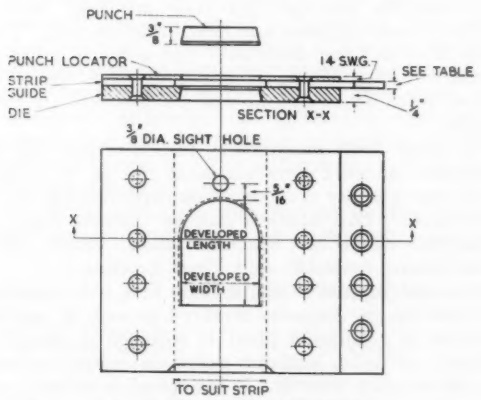
TOOL REPORT — WEEK NO. 36

		TOOLS DEMANDED BY PROCESS		JIG & TOOL D.O.			ISSUED FOR MANUFACTURE						TOOLS COMPLETED					
				CLEARED		OUTSTANDING	TOOL ROOM		COMPOSITE		SUB-CONTRACT		TOOL ROOM		COMPOSITE		SUB-CONTRACT	
Stage	Description	Wkly.	Cum.	Wkly.	Cum.	Cum.	Wkly.	Cum.	Wkly.	Cum.	Wkly.	Cum.	Wkly.	Cum.	Wkly.	Cum.	Wkly.	Cum.
D1	Front Fuselage	10	190	8	128	62	5	38	3	34	-	20	4	12	1	8	6	16
D2	Main Fuselage	1	396	12	260	136	2	76	4	72	6	48	8	28	4	14	10	22
D3	Fuselage (Rear)	4	74	4	48	26	1	15	2	10	1	5	-	12	-	6	-	-
D5 & 6	Bomb Doors	8	20	-	8	12	-	2	-	1	-	-	1	4	-	1	-	-
F1	Centre Section	15	1257	24	982	275	14	250	6	183	4	54	2	120	4	375	-	-
F2 & 3	Outer Wing	22	1406	36	1126	280	17	293	14	326	5	127	7	139	11	223	3	18
F4 & 5	Wing Tips	-	20	-	4	16	-	2	-	2	-	-	-	-	-	-	-	-
F6 & 7	Ailerons	-	48	2	18	30	2	6	-	4	-	-	1	6	-	2	-	-
G3 & 4	Elevators	10	108	9	56	52	3	21	6	12	-	-	4	15	7	8	-	-
G5	Rudder	10	61	4	46	15	3	20	1	13	-	-	2	7	-	6	-	-
G7	Fin	4	44	1	24	20	-	8	1	12	-	-	-	1	3	3	-	-
	Miscellaneous	2	301	10	289	12	10	250	-	-	-	14	1	21	-	4	-	-
	TOTALS	86	3925	110	2989	936	57	981	37	669	16	268	24	365	30	650	19	56

Fig. 6



Standard Drill Set
Large Type not exceeding 6 ins. x 6 ins.



Loose Punch Blanking Tool
Fig. 7

Sub-Contracting Tool Work

There is much difference of opinion regarding the advisability of sub-contracting tool work, but I find that the tool requirements vary so much that the existing Tool Room cannot cope with the big variations—for instance, during one period two thousand tools per month may be needed and six to eight months afterwards, requirements may be down to below the one-thousand level.

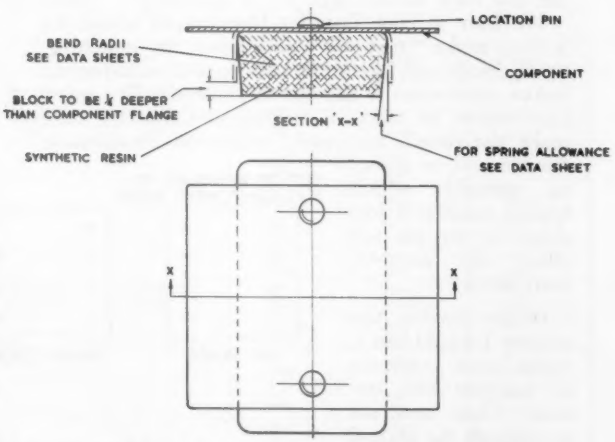
I do believe, of course, in having a very strong Tool Room and that it should look after the most important tools, jig references, etc., but when you are faced with making anything between twenty and thirty thousand tools for an aircraft, the more help you can get the quicker you get the tools and the sooner actual production can be started. It is more difficult, of course, controlling the manufacture of tools at many different factories other than your own, but I feel that if your arrangements are made early enough and proper control is maintained by Weekly Reports and liaison work, the difficulties will be kept within reasonable bounds.

The advent of "Jabroc," "Deleron" and similar types of materials has assisted considerably in getting over the difficulty of shortage of skilled Tool Room labour, as this has allowed the introduction of pattern makers and in our shops this has given us a considerable increase in our tool-making capacity.

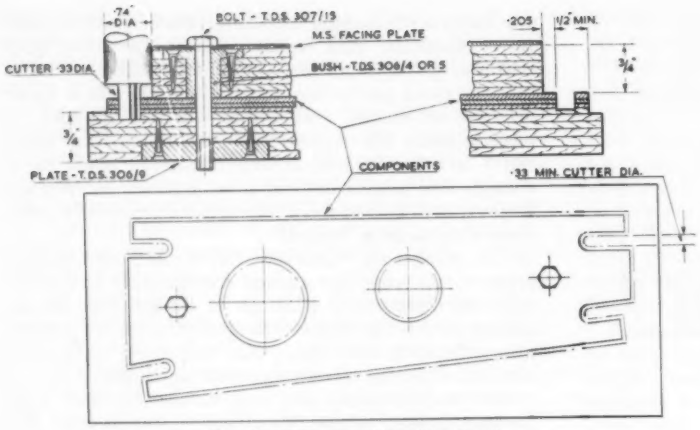
Our tool demands are sent to the Jig and Tool Design Office, where they are divided into the various categories. For instance, tools requiring design, tools which can be made from standard data sheets, tools which are to be made in the Tool Room and tools which can be made by the pattern makers. From our experience, it is only necessary to make special jig and tool drawings for approximately 20 per cent. of the tools required, and the alternative arrangements which can be made for the remainder, considerably speed up the issue of tools for manufacture. The importance of this cannot be overestimated.

Typical examples of Data Sheets used for this purpose are shown in Figs. 7, 8 and 9. It will be seen that these Data Sheets give the information required for manufacturing the tools, and refer to technical information compiled on other sheets for spring back and bend radii. The contour is obtained from full scale templates which are made from lofted reproductions.

The manufacture of tools can also be speeded up by the maximum use of standard details, which can be produced in quantity in the production Machine Shop; Fig. 10 shows typical examples.



Simple Type Hydraulic Press-Bend Block
Fig. 8



Routing Fixture—Movable Head

Fig. 9

I also consider it an advantage to process plan the manufacture of specially designed tools and this section specifies the material required and the machining operations to be carried out, with the result that a complete set of machined parts, along with the standard items, can be issued to the toolmaker for assembly. Properly organised machining can then be carried out, instead of each toolmaker making his own arrangements, which was common practice in the old days.

Tool Inspection

With regard to the inspection of tools, I am of the opinion that the most important point is to inspect the product from the tool and let the inspection of the tool itself merely cover durability, foolproofness, etc.

This practice covers the majority of tools but there are some exceptions, of course, where big and expensive forgings are involved and then it is worth while going to a lot of trouble in checking the accuracy of the tool itself before use.

We have a Tool Try-Out Department whose job it is to make "first-offs" and prove the matching-up of details; all "first-offs" are passed by inspection before production is allowed to proceed. Too much care cannot be taken in making sure that the tools make the details accurately, otherwise considerable trouble will be caused on assembly which, besides causing serious delays on the job, will affect the assembly man hours.

Before leaving this section, I would like to make some reference to machine tool lay-outs. These need not go through the normal tool procedure, but can be provisioned by a special staff located in the Tool Stores in the Machine Shop.

The Lay-Out Engineer receives the detail process sheets and drawings for items which call for machine shop operations. His duties are to make operational machining lay-outs and gather together the tools necessary for the machine set-up and these are stored and issued as kits when required. This section also has its own grinding equipment, etc., so that on returning from use, the tools can be serviced ready for immediate issue.

A typical lay-out for a Number 10 Ward Turret Lathe is seen in Fig. 11, showing that in addition to standard drills, etc., special form cutters and gauges are provisioned for and made in this section.

The record card illustrated enables the lay-out kit to be indexed for quick reference.

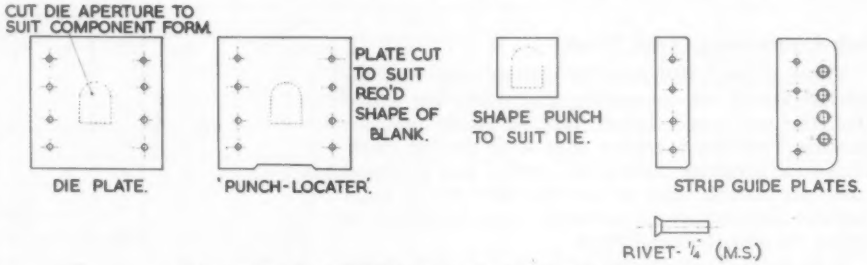
Target Programmes and Capacity in relation to Machine Tools, Floor Space and Labour.

Fig. 12 shows the component programme and the timing of the various stages right back to the date when tools and materials are required, and this is done for all sections of the aircraft.

From this you can get your priorities, both as regards material, tools and detail manufacture. Tools have already been dealt with, but with regard to the manufacturing arrangements, a decision has to be taken as to where details and components are to be made.

If more than one factory is concerned, the distribution of work between them has to be decided and also whether component sub-contracting will be necessary. This analysis can be divided into four categories, that is: Machine Shop, Bench Work, Component Assembly and Final Erection.

Considering the Machine Shop first, it is important to establish the capacity required as soon as possible, because if additional plant is required it should be placed on order without delay to ensure it being available when wanted. It is impossible to wait until every item has had its operational processes laid down, as this is too long a job and it is, therefore,

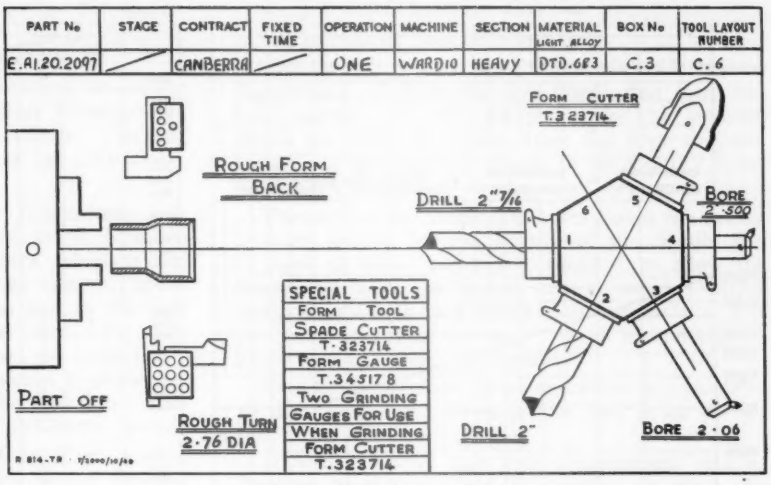

CUT DIE APERTURE TO SUIT COMPONENT FORM.
PLATE CUT TO SUIT REQ'D SHAPE OF BLANK.
SHAPE PUNCH TO SUIT DIE.
DIE PLATE.
'PUNCH-LOCATER'.
STRIP GUIDE PLATES.
RIVET- 1/4 (M.S.)

"Loose Punch" Blanking Tool Set of Standard Parts

Fig. 10

necessary to adopt other methods. It is essential, however, to select all items requiring special machine tools, such as Plano-Millers, Hydrotels, and any large machine jobs, and these items should be carefully analysed, operational times estimated and the number of machine tools required determined.

Regarding the requirements of standard machine tools, these can be estimated by comparison with the known requirements of similar aircraft you have made. This will serve as the first estimate and should be followed up with a more accurate assessment which can be obtained from the process planning sheets, thus confirming the decisions made after the first estimate.



Turret Lathe Layout Card

Fig. 11

The capacity of Bench Work, which is usually associated with an area provided for this type of work, becomes a problem of labour requirements which I will review later.

For Component Assembly, it is necessary first to decide on the number of jigs required, which is done by working out jig times and then, knowing the peak production, it becomes a simple arithmetical problem to establish the jigs required. The Engineering Department can then make a layout of the shops using cut-outs or models, making allowances for out-of-jig space and the equipment stages. An important point to be remembered here is that floor space can be saved or, conversely, more production obtained in the same floor area, by creating as many bench sub-assemblies as possible. This will cut down man hours and major assembly jigs.

The same applies to the erection of the aircraft. If the various components are completely equipped before erection commences, the erected aircraft will be on the assembly floor for a shorter space of time.

In laying out the shop, flow production should be the aim, thus cutting down to a minimum unnecessary movement of parts.

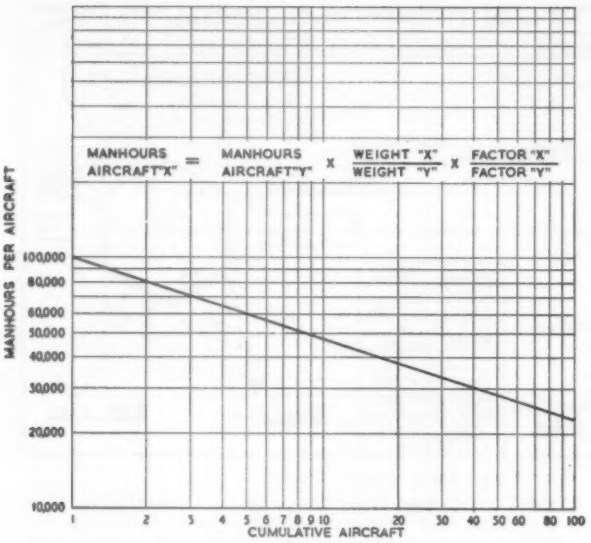
Now, considering the man hour analysis and labour assessment, the method used is illustrated by Fig. 13.

It will be noticed that the man hours for the first aircraft in the new contract, marked "X", are obtained by taking the known man hours for the first aircraft on a previous type, marked "Y", adjusting for the difference in structure weight of the two aircraft, and applying the correction factors. This gives the man hours for the first aircraft and a line is then plotted from this point on log-log paper, with the percentage reduction which applies to your own factory.

TARGET PRODUCTION PROGRAMME — CENTRE FUSELAGE

Set No.	Tools Available		Raw Material		Detail Manufacture		Sub Assemblies Complete	Structure Completed	Fuselage Equipped
	Structure	Equipment	Structure	Equipment	Structure	Equipment			
1.	Oct/Dec 1949	Mar/May 1950	Oct/Dec 1949	Mar/May 1950	Feb/May 1950	June/July 1950	July 1950	Oct 1950	Jan 1951
2.							Sept 1950	Dec 1950	May 1951
3.							Nov 1950	Feb 1951	May 1951
4.							Jan 1951	April 1951	July 1951
5.							Feb 1951	May 1951	Aug 1951
6.			June/Aug 1951	Nov/Dec 1951	Oct 1950 Jan 1951	Feb/Mar 1951	Mar 1951	June 1951	Sept 1951
7.							April 1951	July 1951	Oct 1951
8.							May 1951	Aug 1951	Nov 1951
9.							May 1951	Aug 1951	Nov 1951
10.							June 1951	Sept 1951	Dec 1951

Fig. 12


MANHOURS AIRCRAFT "X" = MANHOURS AIRCRAFT "Y" X WEIGHT "X" / WEIGHT "Y" X FACTOR "X" / FACTOR "Y"
MANHOURS PER AIRCRAFT
100,000
80,000
60,000
50,000
40,000
30,000
20,000
10,000
1 2 3 4 5 6 7 8 9 10 20 30 40 50 60 80 100
CUMULATIVE AIRCRAFT

Month	Programme Mthly	Programme Cum.	Aircraft Man Hours	Labour Required Details	Sub Assy.	Main Assy.	Erection	Total
Mar.				30				30
Apr.				45				45
May				60				60
Jun.				88				118
Jul.				100	100			200
Aug.				105	104	75		284
Sep.				116	152	150		418
Oct.				128	175	180	30	513
Nov.				146	186	303	40	675
Dec.				160	197	323	56	736
Jan.	1	1	100,000	160	220	348	82	810
Feb.	1	2	80,000	160	252	360	95	867
Mar.	2	4	135,000	160	278	368	102	908
Apr.	2	6	116,800	160	278	388	106	932
May	3	9	154,800	160	278	427	117	982
Jun.	3	12	140,000	160	278	445	136	1019
Jul.	4	16	170,000	160	278	445	149	1032
Aug.	5	21	194,300	160	278	445	149	1032
Sept.	6	27	214,000	160	278	445	149	1032
Oct.	7	34	230,000	160	278	445	149	1032

Fig. 13

The Americans work on an 80% reduction, this being the average established during the war for the American industry, and this has been used on my graph, although it will vary from factory to factory according to the particular organisation.

To apply this formula it is necessary to accumulate knowledge of past achievements, and I cannot stress too strongly the importance of building up this information, month by month, in order to get the necessary background.

The man hours for each aircraft are then taken from the graph and related to the aircraft programme as shown on the diagram. For the purpose of completing this graph we call for :—

Erection labour two months before aircraft delivery.

Main Assembly labour four months before aircraft delivery.

Sub-Assembly labour six/seven months before aircraft delivery.

Detail labour nine/ten months before aircraft delivery.

These, of course, will vary according to the type of aircraft being produced.

The Problem of Labour

The next problem to solve is whether it is possible to obtain the required labour, and close liaison with the Ministry of Labour in the area will help to decide the possibilities of meeting labour demands. This information, along with the machine tool and floor space analysis, will then allow a decision to be made as to how much sub-contracting, if any, will be required.

It is now necessary to decide on the size of the manufacturing batches which will be issued. I always think it wise to make the first batch relatively small, as this is where all the tool troubles will be met, although many will have been caught by the Tool Try-Out Department. The smaller batch will obviously get through the machine shop more quickly and allow an early start on sub-assemblies. This is particularly important, as the sooner the assembly people learn what it is all about the better. An early start gives them more time and allows the department to be built up more gradually.

You will note that the aircraft is divided into its main components and each component is divided into structure and equipment. The total number of details required to make any of these sections is declared and the following columns show the weekly movement and accumulative totals. This information thrown up each week does allow an executive to keep a grip on this very important part of the job and furthermore, it gives him warning early enough for him to take action if necessary.

One of the difficulties of the Machine Shop Superintendent and Foremen is to keep control over the many thousands of details required to make an aircraft, and I have exercised my mind quite a lot in order to try to find the simplest way in which this matter can be handled by the floor supervision.

I feel that putting Week Numbers on the Job Cards when they are issued does greatly simplify the position. The commencing Week Number is marked on the card, together with the finishing Week Number and this gives the shop supervision a convenient way of making sure that jobs are started to time. If this is done, there is a reasonable chance of getting the items finished when they are required.

Issuing the Job Cards

The pre-production arrangements being completed, that is, tools having been made available and materials received, it is now necessary to issue the Job Cards. As I have stated, the Control Records are

in component order and this enables the Job Cards to be issued in the correct priority. To do this, the Control Room issue a Piece-Part Programme.

Fig. 14 shows the programme which is issued by the Aircraft Control to the Piece-Part Division and is the only authority for issuing Job Cards. You will notice that again one piece of paper has been made to do a number of jobs.

First, the Controller issues the Programme and states the Job Number, Stage and Week Number when the items are due in the stores, which is the completion Week Number, and then lists the items required. The Programme is then sent to the Job Card Issue section. This section raises the Job Cards, enters on the programme the Job Card number and ticks the Job Card column to show the card is completed. The Programme and Job Cards are then passed over to the Piece-Part Control Room.

With each Job Card is a Route Card and a Material Requisition. The Control Room file the programme in Serial Number sequence, which puts it into priority order, and then sends the Material Requisition for material allocation and the Job Card to the Tool Control as a final check to ensure that the tools are available, keeping the Route Card as evidence that the checks are being made. In this section are three boxes in which Job Cards are divided into the following groups :—

1. Job Cards held for Tools and Material.
2. Job Cards held for Material only.
3. Job Cards held for Tools only.

This control point is very important, as it enables Supervision to check the Job Cards that have not been started and gives the reason for the hold-up. When the cards are cleared from this stage they are issued, *via* the Material Stores, to the Control Point at the first operation on the card.

Throughout the factory, Control Points are set up at each section for the control of the details and at each of these, boxes are provided to allow the Route Cards to be sorted out in aircraft order, component order and Week Number order. The cards are also separated into " Work in operation ", and " Work awaiting operation ".

As each item moves from operation to operation, so the Route Card moves and is filed in its correct box.

It will be seen that this arrangement enables Progress Staff and Floor Supervision to check the position from day to day.

When the details are completed, the Job Card is returned to Aircraft Control and the Route Card to Piece-Part Control, to enable the records to be completed and the Control Card signalled.

Component Assemblies

Next, let us consider Component Assemblies. These will already have been analysed and broken down

A/C. TYPE — STAGE: EA3·00·143 — DATE ISSUED: 3·2·52 — BATCH No.

PIECE PART PRODUCTION PROGRAMME — № 55134

JOB No.: 145 / 01000 / 50000 — DATE DUE IN STORES: 10·4·52

CONTROL POINTS: 1 TURNING; 2 DRILLING; 3 MILLING; 4 LIGHT PRESS; 5 HEAVY PRESS; 6 DROP HAMMER; 7 WOOD DETAILS; 8 MANIPULATION; 9 METAL DETAILS; 10 DETAIL FITTERS; 11 INSPECTION; ASSEMBLY DIVISION; SHIPIRE

PART No.	FINAL ASSY.	QUANTITY REQUIRED	JOB CARD No.	PROCESS SHTS	JOB CARDS	TOOLS	MATL ALLOC'	STEEL STORES	1 TURNING	2 DRILLING	3 MILLING	4 LIGHT PRESS	5 HEAVY PRESS	6 DROP HAMMER	7 WOOD DETAILS	8 MANIPUL-ATION	9 METAL DETAILS	10 DETAIL FITTERS	11 INSPECTION	ASSEMBLY DIVISION	SHIPIRE	QUANTITY REQ.	QUANTITY STORES	
EAI·20·1445	8/12	25	EA/10461	/	/	/	/	/		1			24·5					B	EC6				25	26/3/52
EAI·20·1447	8/12	25	10462	/	/	/	/	/						1·2			3·4	B	EC.			1	24	9/4/52
EAI·20·1449	8/12	25	10463	/	/	/	/	/					1·245				3	B	EC6			1	24	26/3/52
EAI·20·1451	8/12	25	10464	/	/	/	/	/					1·245				3	B	EC6				25	17/3/52
EAI·20·1453	8/12	25	10465	/	/	/	/	/		2		1·4						B	EC5			1	24	4/3/52
EAI·20·1455	8/12	25	10466	/	/	/	/	/					1·246					B	EC6				25	10/4/52
EAI·20·1457	8/12	25	10467	/	/	/	/	/					1·245					B	EC6				25	9/4/52
EAI·20·1459	8/12	25	10468	/	/	/	/	/					1·245					B	EC6			5	20	18/3/52
EAI·20·1471	8/12	50	10469	/	/	/	/	/		2		1·4						B	EC5				50	10/4/52
EAI·20·1473	8/12	200	10470	/	/	/	/	/		2		1·4						B	EC5				200	3/3/52
EAI·20·1477	8/12	300	10471	/	/	/	/	/		2		1·4						B	EC5				300	5/2/52
EAI·20·1479	8/12	50	10472	/	/	/	/	/		2		1·4							EC5			8	42	4/3/52
EAI·20·1483	8/12	50	10473	/	/	/	/	/		2		1·4						B	EC5				50	17/3/52

R.1916/AC

Fig. 14

into sub-assemblies, which can either be assembled on the bench, or in subsidiary jigs. This is a considerable help to production, as it allows a better distribution of labour and cuts down the number of major assembly fixtures required.

The building of the main components should also be broken down into a series of operations, to facilitate assembly and assist in getting more realistic piece-work prices. It is well known that until piece-work prices are fixed it is impossible to get maximum effort from the men, but as soon as the men have had time to learn the job and assembly snags are cleared, then the Rate-fixers should begin to operate.

Fig. 15 shows a typical Weekly Report showing how progress can be checked.

From this it will be seen that the man hours being taken on each set are recorded and in the table in the corner the number of operations is given, together with those priced. This allows a ready check to be made by executives and action taken where necessary.

With regard to the equipment of the aircraft, exactly the same procedure is followed as with component assemblies, but I think it is even more important to break down the equipment into sub-assemblies which can be made away from the aircraft, as there is usually very little space in the fuselage in which to work.

Much time can be saved by the use of mock-ups for establishing Pipe Templates, Electrical Runs, Looms etc. and these should be arranged as early as it is possible to do so. Great care should be taken to ensure that the mock-up is a true reproduction of the aircraft structure.

The importance of keeping a tight control over the fixing of piece-work prices on the jobs referred to above is emphasised, when it is considered that 80% of the man hours on an aircraft are used on parts other than details.

Programmes are issued for major components and a weekly meeting is held to review the position in relation to this programme. The shop problems can then be discussed, shop supervision notified of any new developments which may affect the programme and directives given to the people concerned.

Final Assembly

We have now reached the Final Assembly stage and if the interchangeability problems have been properly handled, there should not be much difficulty in erecting the aircraft. What is most essential is to see that the various test rigs to prove pressurisation, hydraulics, etc. have been planned well ahead in order to ensure that they are available when required. The same remarks go for any ancillary equipment which is peculiar to that particular aircraft.

The personnel in charge of flight testing should also have previously made out their full flight test schedule, so that no time is lost when the aircraft is handed over to them.

COMPONENT MANHOURS

FRONT FUSELAGE STRUCTURE

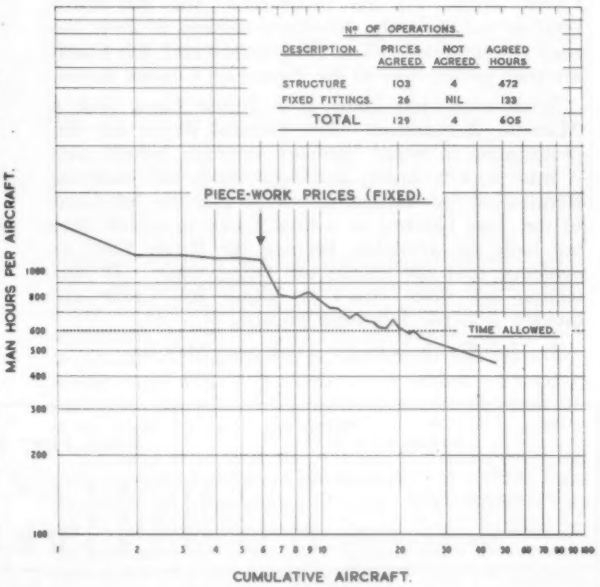


Fig. 15

I have tried to show you that with careful planning and suitable Weekly Reports to check the position at the various stages, it is possible to keep a grip on the situation and although this can be and is affected by circumstances outside your own control, proper organisation will minimise their adverse effect.

No job runs as smoothly as we would like and it requires persistent effort, coupled with a spirit of not being beaten, to get the best results. I am reminded of some words by Benjamin Franklin which run:

"Drive thy business, let not thy business drive thee."

(*Continued from page* 153)

a "shot in the dark" is taken which never quite hits the target or meets the requirements. As a result, the production line is generally robbed of many important items to feed the operators and keep the early machines in the air. The negative effect on production cannot be overstressed, neither can the delays caused be predicted. All that we can say is that the effect on "Prototype to Production" is generally most discouraging to Production Engineers.

Production Engineers who have the task of creating a production line of aircraft have many difficult problems to face, and it is upon their skill and ingenuity that success can be measured. I strongly recommend that all Production Engineers who are interested should make a study of some of the problems I have mentioned.

PROTOTYPE TO PRODUCTION

PART 2

by H. POVEY, A.F.R.Ae.S.

Mr. H. Povey

Mr. Povey has spent 38 years in the aircraft industry, starting as an assistant designer at the Royal Aircraft Factory at Farnborough, in 1914. He joined the de Havilland Company in 1924 and after two years in the Design Office, was appointed Chief Inspector.

Following the initiation at Stag Lane, in 1934/35, of the manufacture of controllable propellers, Mr. Povey visited America to study production and inspection technique and on his return the management of the new department was added to his duties.

Shortly before World War II, Mr. Povey was appointed Production Manager of the Aircraft Division at Hatfield, when his major task was the production of the Mosquito, both in the U.K. and in Canada. After a short period as Chief Inspector, he took over the General Production Managership, and has organised the manufacture of the Dove, Chipmunk, Vampire, Venom and Comet. He is now Works Director of the Company.

IN creating a production line, following the completion of a prototype and its initial flight trials, Production Engineers are faced with many difficulties.

The period between the first flight of the prototype aircraft and the commencement of production deliveries is generally regarded as excessive, and the purpose of this Paper is to elucidate some of the difficulties and to examine the best means by which this period can be reduced to the minimum. In my experience, the period varies for different categories of aircraft, as follows:

Light aircraft, such as trainers	1 - 2 years
Medium type aircraft	1½-2½ years
Large type aircraft, embracing air-liners	3 - 7 years

A brief examination of the elements which control this period can be placed under the following headings for examination and, in this Paper, particularly relate to civil aircraft:

1. Financial risk;
2. Test flights and flight for Certificate of Airworthiness;
3. Tooling, under the following sub-headings:
   - (a) The extent to which parts should be fabricated by freehand methods;
   - (b) The extent to which temporary tools can be employed;
   - (c) The financial risk incurred by modifications;
   - (d) Type of tools to be used, with special reference to producing large numbers of tools in the shortest space of time;
   - (e) Tool design and compromise;
   - (f) Liaison work with the design staff;
   - (g) Planning and Production Engineering.

It is under these headings that decisions have to be made at a very early stage if the gap between the flying of the prototype and the commencement of deliveries from a production line is to be reduced to the minimum.

On civil aircraft, the decisions we have to make to achieve the minimum period are greatly influenced by competition, particularly competition from abroad.

If the aircraft specification happens to fulfil the requirements of a potential customer, he will invariably become interested at the commencement of design. He will generally make tentative enquiries, but before proceeding further he will wait until the flying of the prototype. If he then learns that the chances of success are good, he will begin to press his enquiries in a more finalised form and will ask for guaranteed delivery dates, performance and price.

It is at this stage that the pressure on the Company becomes great and generally results in a desperate effort to reduce the gap and to obtain production at the earliest possible date.

(*Note: I am using the Comet to illustrate the points I have to make in this Paper, and I have chosen this aircraft to make my subject matter factual, but the data quoted is applicable to any other civil type of aircraft in the same category.*)

Now, let us examine under these headings what is involved to give delivery in the minimum time.

Financial Risk

Once we have committed ourselves to guaranteed delivery, performance and price (which we did in the case of the Comet), we are forced at an early stage to commit ourselves to a heavy financial risk. We decided from the onset to allocate a sum of money, running into seven figures, for tooling and the procurement of materials and equipment, and I would ask you to appreciate that this was a risk taken by private enterprise.

Test Flying and Certificate of Airworthiness

In order to obtain early test flying to eliminate snags and subsequent flying, and to obtain the Certificate of Airworthiness for early delivery, we realised that the prototype must be got into the air at the earliest possible moment and no effort could be too great to achieve this objective.

The Comet, being the first civil jet air-liner, became somewhat of a guinea-pig with regard to Certificate of Airworthiness requirements and in addition to the prototype, much work was done on the second and third production aircraft before the final test work for certification was completed on the fourth. I mention this to show how essential it is to reduce the gap between the flying of the prototype and the time when other aircraft are capable of taking the air.

Tools—Freehand Fabrication

To make some progress before tools were available, we decided to manufacture five sets of all parts, where possible by freehand methods. This particularly applied to machine shop items and tools were only made for those parts which required interchangeability of major components, or where it was impossible to manufacture without tools. All other items were marked out and machined by freehand methods.

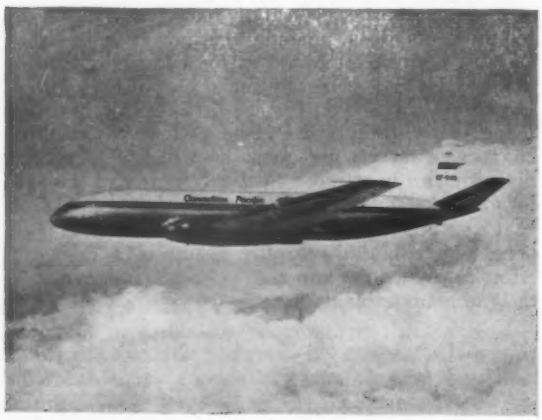


Fig. 2

The first Mark IA "Comet" aircraft (44-seater).

Fig. 1

First production "Comet" aircraft, flown 12 months after the prototype. Four of these were delivered $2\frac{3}{4}$ years after the completion of the prototype which enabled commercial operations to begin. A total of nine were delivered to B.O.A.C. $3\frac{1}{2}$ years after the prototype had flown.

Extent to which Temporary Tools can be Used

This is very important and, in order to get early production, the strongest possible liaison and team work is essential between the experimental and production departments. By careful arrangement of experimental lash-up jigging used for the prototype aircraft, a great quantity of this tooling can be re-arranged and quickly modified to give good production tooling.

It is frequently necessary deliberately to duplicate tooling in the early stages in order to close the gap. By this duplication, I mean that a large volume of temporary tools is produced for the purpose of a small initial batch. These are eventually replaced by duplicate tools of a more permanent nature, and these can be fabricated while production proceeds from the parts produced by the initial temporary tools. This represents a fairly heavy expenditure but it does assist in closing the gap.

Modifications

This is a risk which cannot be assessed, but it is one which a progressive Company must have the courage to take. If we wait until the design is stabilised and every part is approved, then the period of time will be great between the completion of the prototype and the start of production. By proceeding with production before the prototype has flown we are indeed incurring a very heavy financial risk but, in our experience, the risk has always been worthwhile. As a yardstick, I can disclose that we did proceed with the Comet, irrespective of modifications, in an attempt to narrow down the gap and, as a result, have incurred a loss of £350,000 to date due to scrap and changes—quite a lot of money, but a small insurance premium to ensure early delivery.

I fear to think what would have been the consequences had we been nervous and reduced this risk to the minimum.

It would have meant literally no Comets today, with the loss of good business and prestige but, against this risk, which was taken by private enterprise, we have now been reasonably successful.

Type of Tools to be Used

As the number of tools required to produce a modern air-liner is growing with every type of new design, there is a great scope for Production Engineers under this heading. This particularly relates to methods of producing a large volume of tools in the shortest possible period of time, and the problem is one which requires the closest possible study. Briefly, the problem may be examined as follows:

(1) methods by which the number of tools can be reduced by suggestive re-design of components, in conjunction with the Design Office;

(2) how to deal with the remaining volume of tools in the shortest possible time. To assess this one must eliminate increase in man power as the only answer.

It is here that the Production Engineer can really show his ingenuity.

In order to achieve this feature on the Comet, we decided considerably to improve and expand our methods of plaster and concrete moulding. By the use of the aircraft loft, in conjunction with the concrete mixer, domestic building bricks, sand and a number of plasterers we were successful in producing, in a very short period, large numbers of accurately-shaped metal-forming tools for the stretcher press and Hufford press, and plaster patterns for drop hammer and Redux tools, and the same system was used to produce tools for glass cloth and Perspex mouldings.

Tool Design and Compromise

Under this heading, Tool Designers and Production Engineers who have to start a production line at an early date in relation to the prototype, can do a great deal by co-operation between jig and tool design and jig and tool makers. In many instances, only the basic design of some tools needs to be considered in the Design Office, and the completion of these tools can be safely left to the jig and tool makers to work from the component drawings and, in some cases, from accurate wooden models. This eliminates a considerable volume of jig and tool design work and by this compromise, we can release the more important jig and tool designers to deal with those jigs and tools which must of necessity be carefully designed, and where draughtsmanship is required to ensure accuracy in the design of the jigs and tools.

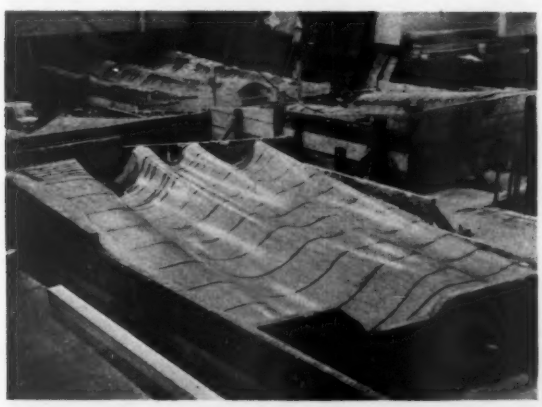


Fig. 3
Large, complicated plaster model.

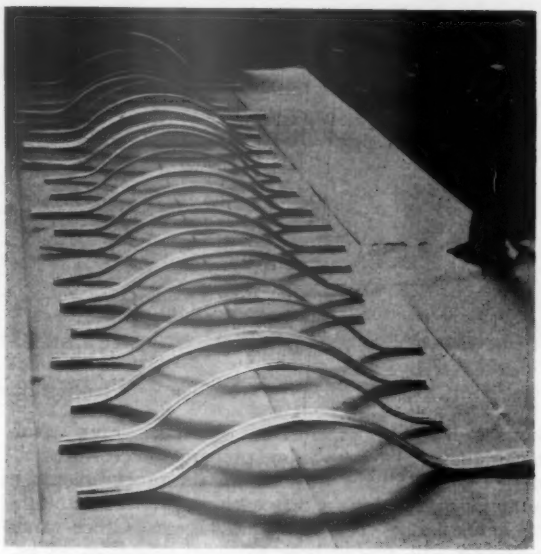


Fig. 4
Cowling formers made from precision cast concrete tools.

Liaison with Design

To ensure success, a strong liaison must be created between the design and production departments. The Production Engineers must be consulted by the designers at the earliest possible stages in the design. In my Company, we locate several senior Production Engineers in the various sections of the Design Office, to give general practical advice in the early scheming stages of the aircraft and to assist generally in developing new methods and techniques at an early stage. This procedure enables production to proceed parallel with the prototype. This liaison is very essential if we are to reduce the gap and achieve the desired results in the simplest possible manner.

Planning and Production Engineering

Planning and Production Engineering must be closely coupled together and, if this is worked in conjunction with the liaison engineers situated in the Design Office, and to whom I have referred under the previous heading, I am sure the maximum benefit will be achieved in obtaining early production.

This system enables the liaison engineer attached to the Design Office to pass preliminary information to the planning and engineering sections. It enables the Production Engineer to take action in the early

Fig. 5

Battery of precision cast concrete tools made to produce the cowling formers.

stages of development of new processes and techniques. He can also prepare process sheets, design jigs and tools and arrange the procurement of essential materials at a very early stage.

Good liaison between the Design Office and planning will enable bulk material schedules to be produced early and, although these may not be accurate, it is one of the financial risks we accept in placing early orders as a means of eliminating delays at a later stage.

Methods Engineers must also be stationed in the production departments, to guide the project through the initial stages of production. Their duties are to eliminate snags in tooling, to make constructive criticisms of design and to ask for design changes with a view to improving quality and reducing cost. This relieves the shop supervision of a troublesome task and enables them to concentrate on the more essential duties of directing and controlling their labour.

Conclusions

Before closing my Paper, I would like to add several items which have not been mentioned under

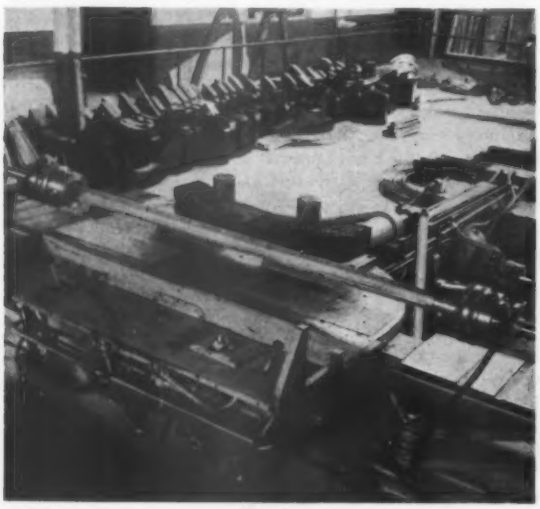


Fig. 6

Fig. 7

Precision cast concrete tools in use on a Hufford machine.

Fig. 8
Precision cast concrete tools in use on a Hufford machine.

the headings and which do create difficulties in generating a production line.

The large volume of work which has to be done between the flying of the prototype and the start of deliveries from a strong production line is a major problem.

The prototype is usually flown as a shell and the final finishing and special equipment is generally left by the Design Office to be dealt with at a later stage. During the period between the first prototype flight and delivery, some of the major problems we have to deal with are as follows:

Design of jigs and tools;
Manufacture of tooling for production;
Development of production methods and techniques;
Arranging the final breakdown of the machine into its most suitable components for production;
Writing up all process sheets and operation schedules; on the Comet we have written up 52,000 layouts and process sheets;
The development of jigging and tooling to enable the maximum use of semi-skilled labour;
The elimination of production snags;
Establishment of piece-work time on detail manufacture, component manufacture and final assembly;
The elimination of snags, especially during flight test;
Embodiment of modifications;
The factory layout has to be considered, and particularly the assembly line;
Arrangement of test equipment on the assembly line and also test equipment for components;
Manufacture of full scale components for physical test;
The procurement of special equipment for functioning tests in the decompression chamber at high altitude and low temperatures;
Testing of the fuel system in the test laboratory, with particular reference to the behaviour of fuel at high altitude and low temperature, also at low altitude and tropical conditions;
The physical and metallurgical testing of the initial batches of all forgings for strength and grain flow;
Critical examination of all castings by X-ray and the establishment of casting technique.

On prototype aircraft, it is usual for the designers to use many temporary manufacturing methods in order to get their aircraft into the air as quickly as possible. These have to be eliminated by design and production methods developed before the production aircraft get under way.

Inspection has not been mentioned in this paper, but has an important part to play. The method of inspecting the prototype is generally entirely different to the method of inspecting the production aircraft. Prototype inspection is generally more individual and confined to the Experimental Department, and much is done by contact between designers and the Inspection in clearing temporary jobs. On production, this is not permissible.

During the period of time between prototype and production, Inspection must make any necessary breakdowns and introduce their recording methods. They should establish suitable methods of inspecting components at an early manufacturing stage, so that when these components are eventually embodied in the final aircraft many months after fabrication, the records will show the actual modification standard at the time they were produced.

In attempting to close the gap to a minimum we must not forget one important item—the provisioning of spares. It is useless to generate an early production line and give deliveries to customers without a strong spares backing. The provisioning of spares is quite a difficult problem, particularly as there is no way to determine accurately the numerous items which may be termed "consumable". Generally

(*Concluded on page* 148)

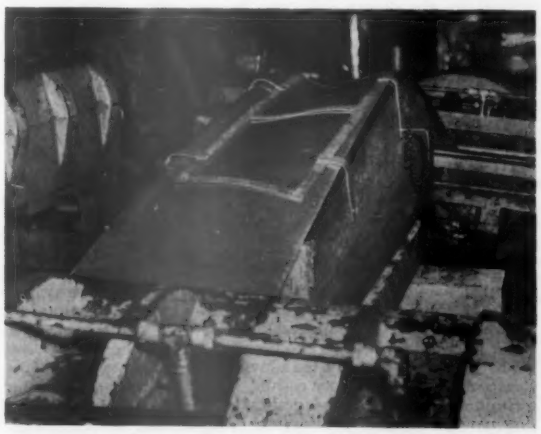


Fig. 9
Precision cast concrete tools in use on a Sherican press.

DESIGNING FOR PRODUCTION

REPORT OF DISCUSSION FOLLOWING SESSION I OF THE SOUTHERN SECTION CONFERENCE

Chairman:

Professor E. J. RICHARDS, M.A., B.Sc., F.R.Ae.S.

MR. W. W. W. DOWNING (*Production Manager, Gloster Co. Ltd.*), in opening the Discussion, congratulated the authors on two most interesting papers. Mr. Low had emphasised the importance of meeting production programmes, but the Production Engineer could not do this unless the designer gave him a "makeable" product and the drawings, in correct production sequence in good time.

Both authors had outlined most of the present-day techniques, but the point in which Mr. Downing was most interested was the policy of co-ordination between design and production which would enable the Production Engineer to have his say at the right time which was, of course, at the outset. Mr. Walker had dealt with this and Mr. Downing supported him in saying that at the Gloster Aircraft Company, this scheme was working well. Dr. Russell had not said how the techniques which he had mentioned had been tried out in order to arrive at his conclusions. At Gloster Aircraft, these are always carried out by the normal production departments, in order to obtain true production data, since it had been found that experimental departments would resort to clever "hand" methods, by which they could achieve almost anything!

The techniques outlined by both authors would no doubt change as rapidly in the future as they had in the past, and the part which the Production Engineer must play in the initial co-ordination between design and production must become more and more important as the aircraft became more complex.

DR. A. E. RUSSELL said that new techniques were usually started by the design side, not because they wanted to do so, but because there were not enough people on the production side to do development work.

It was about time that the production side took on more technologists for development work. The production people were brought in as soon as possible, but usually they were so busy on their immediate problems that they had not the time to give the requisite thought to new problems, and perhaps were not sufficiently interested in them at that stage. They could not play a part until they knew what they were talking about, and to do that they needed specialised training and freedom from immediate production worries.

MR. R. E. MILLS (*Senior Designer, Bristol Aeroplane Company, Ltd.*), asked Dr. Russell to enlarge on his remarks about technicians going on to the production side. He himself, he said, had strong views on this matter and would like to suggest the development, first, of what he would call the production research engineer, who could be very usefully employed, not in convincing his Company of the necessity to buy new plant to carry out the techniques for which the designers asked, but in investigating new methods of production; and, second, on the design side, of the production designer. Rather than a highly-qualified technician, the latter should be someone who had had working experience of both production and design and who was, therefore, capable of translating the production research engineers work into design features.

Mr. Walker had mentioned the question of "productionising" drawings. Mr. Mills' experience of this, unfortunately, had been that it was generally a question of correcting mistakes which had been made originally. Productionising as such, he felt, should come more from a knowledge of the technique which was to be applied to manufacture after the prototype had been made.

MR. WALKER, in reply, said that he had been referring principally to the method of presentation of production drawings for the prototype, as against experimental drawings. The experimental drawings were those which were not split up into the same amount of detail; one had a frame and half-a-dozen fittings and left it to the experimental shop to make the best they could out of it. There had been a mistaken idea in the past about experimental drawings—in the long run they lost time instead of saving it.

To the suggestion of having a structures designer he would reply; "Heaven forbid!" There were enough specialists at present and it was not necessary. What was important was to make the Drawing Office production-minded, and it was only by bringing in the production people who had to make the articles that this could be done. Two firms might have different ideas about how to make a certain article; it depended on the skill of the processing people and on the Production Engineers giving their ideas according to the plant which they had in the factory in the first place.

The first question, however, was whether the part need be made at all, and whether there should be a forging in place of a small sub-assembly. A great many factors were involved in deciding on the production job.

MR. D. GAMMELL (*Engineer, T.G.1, Ministry of Supply*), thought it was true to say that the design side of the aircraft industry had made better progress than the production side. If a comparison were made between producing motor cars and producing aeroplanes, it was of course true that the former were produced more quickly and cheaply. But if regard were had to the conditions in which the two things were made, it must in fairness be admitted that the production man on the aircraft side worked under a handicap. For example, for whom were aeroplanes made? Mainly for the Ministry of Supply, which treated the development side very well and gave them contracts for development work; they could spend a great deal of money under those contracts in developing ideas and methods in their own ways.

The Production Engineer was not in the same position; he had to produce an aeroplane as cheaply as possible under the worst possible conditions—for example, in small quantities.

Mr. Gammell thought some system should be developed,

for which the Ministry would be mainly responsible for spending money on production research. If this question could be taken up, and if the main customer—the Ministry—could give contracts for production research, he felt that the disparity which existed at present between the performances of the design and production sides would be greatly narrowed.

MR. W. A. SALES (*Director, Aircraft Production Development, Aircraft Supplies Division, Ministry of Supply*) said that he had been appointed with the idea of pursuing the subject of production development, generally fostering the spirit of introducing new ideas on manufacturing techniques and processes. He agreed fully with the remarks which had been made, but it was important to bear in mind that one started off with designers who had served an apprenticeship many years ago, and who had not had much opportunity thereafter to keep their ideas up to date or keep in touch with new developments on the production side.

The greatest difficulty in production, seemingly, was to get new views accepted. He had found it extremely difficult to put over new ideas to designers, who had a job of their own to do and liked to get on with it as quickly as possible with their present experience and background. He thought that the type of get-together which took place in the Gloster Aircraft Company had been a most valuable contribution, for the simple reason that the designer began to get a better understanding of the Production Engineer's difficulties, and *vice versa*.

The outcome of that get-together should be most valuable, in the sense that the designer would be designing with a much broader background and knowledge, and sound ideas would be put into the design right from the start.

MR. A. VINES (*Production Manager, Fairey Aviation Company Ltd.*) suggested that the problem was much more fundamental than had so far been admitted. The fact remained that it was only during the War they started making metal aircraft; they had not known how to do it in 1936. The design people, to begin with, did not know how to design a metal aircraft; that had been obvious by the chaos which arose during the War in trying to produce aeroplanes designed by the then design staff. That was an established fact.

Two designers had now admitted in public that they were attempting to get their Design Offices to produce a design which was capable of production in sub-assemblies, which were essential for mass production. The trouble was that the Design Office suffered from lack of good designers, and the production side from lack of good production personnel who had been trained in a Design Office. It was quite an impossible situation to expect a man who had been trained in a machine shop, or a press shop, or an assembly shop, to go into a Design Office and argue with the designer. The fundamental point was to educate more Production Engineers capable of working in the Design Office and talking the language of aircraft designers.

Mr. Vines' company had started to do something in this direction, but had not gone far enough. In 1943, they re-organised the Jig and Tool Office and called it "Production Development", and a scheme was devised whereby the work was in three groups—assembly; machining; and platework and press work. The Assembly Development Engineer went in on the prototype from the beginning and worked with the design and project engineers. The better the quality of the labour from the tooling and production point of view, the better the component obtained in the end, because the design staff could be put on the right lines from the beginning.

The problem had been to get the right personnel properly trained to do that type of work, and that was where the aircraft industry at the moment was suffering, partly because of a hangover from the War and partly because at the end of the War, many good people left the industry and returned to their peace-time jobs. Two years ago, many firms in the aircraft industry did not know where their next job was coming from; but now, out of the blue, they had to double and treble their staffs. The country would have to face the problem of training and establishing the right men, to whom the designers would listen and with whom they could argue. That must be backed up by research contracts from the Ministry of Supply.

Mr. Vines had approached a number of machine tool firms in the U.K., and their answer had been: "We are not interested in the aircraft industry. We are far too busy". If the country was going to take the making of aeroplanes seriously, it would have to provide a steady flow of work, especially new work, and financial support to enable machines to be developed and aircraft produced.

A Member expressed amazement at hearing Mr. Vines say that they had not known how to build metal aircraft before the last War. He himself had been building them in 1922.

The challenge had to be faced by the design staff, to go back to simplification. New plant, forgings, and far more elaborate sub-assembly jigs were required than ever before, and that meant delay in getting jobs into production. There should be a return to simple designs.

MR. L. W. ROSENTHAL (*Co-ordinating Engineer, Saunders Roe, Ltd, I.O.W.*) referred to Mr. Low's statement that more people would have to come into the industry to produce more aeroplanes, and that such production was a very long process. It was well known that this aircraft production time was increasing rapidly. Some of the reasons for that had already been mentioned, but what was the size of the problem? The man power limitation would, he thought, be the ultimate one, particularly under emergency conditions, and he hoped that during the discussion an idea would be given of what was happening on this problem in the industry and in the country as a whole, to indicate how much research was necessary.

Having regard to the complexity of aeroplanes, it might be desirable to go through all the safety regulations and scientific ideas and see how many could be cut out. They had to ask themselves what they were setting out to do. Machined skins were something everybody was going in for, but could they afford it? Could Dr. Russell give some idea of the relative cost of machined skins compared with those which were reduced? The object was not simply to save money, but to save calendar time and man hours.

Mr. Rosenthal asked if any members had anything to say about their methods of training Design Office personnel to be conscious of the production aspects of the job, and of training people on the production side to be conscious to design problems. Several speakers had said that it ought to be done, but was there anywhere in the training programmes for the industry and in the companies, a lead which other people could follow?

MR. E. J. BOULGER (*Methods Engineer, Westland Aircraft, Ltd.*) said that he could speak with some confidence on the subject of co-operation between production and design, having spent half his working life on design, and the other half on production. There had been a considerable drift from design to production, almost entirely in senior positions, and the senior members of the production departments in most companies were well aware of the designers' problems. They knew it was no good talking about complexity and difficulties and asking for them to be done away with; they were engaged in the manufacture of a product which was bound to be complex and difficult. There was, however, very little realisation on the design side of the problems encountered in production, particularly at the lower levels.

He had found, on many occasions, that when it was suggested that something should be altered to simplify manufacture, the designer started talking about moments of inertia, and so on. Mr. Boulger referred, perhaps, not so much to the designer as to the detail draughtsman, the man who caused most of the Production Engineer's troubles. If he found that one knew what the moment of inertia was, he would be quiet. Unfortunately, the average process planner did not know and therefore could not argue. The average process planner in the aircraft industry started, perhaps, ten years ago and had been recruited from the workshops in much the same way as foremen. At present, the best apprentices went into the Drawing Office, the middle group went into Planning Offices, and the worst remained in the shops.

The basic difficulty, Mr. Boulger thought, was to train really good planners, and the only means of doing that was to make the process planner's job one worth having; in other words, he should be roughly the same as a draughtsman in ability and status. There should also be more planners transferring to the Drawing Offices, just as draughtsmen had moved into the Planning Departments.

He had taken part in production conferences between the Design Office and the Production Department. They were very good, but a great deal of time was spent in discussing large items with a tendency to ignore small detail parts and sub-assemblies. It was well-known that an aeroplane could contain up to 20,000 different detail parts, and if these were badly designed the Production Department could be wasting time on difficult operations with no corresponding benefit to the technical performance of the aircraft.

It was at the lower levels, the ordinary detail draughtsman and the ordinary planning engineer, that there was need to train better people.

Mr. W. Browning (*Director and General Manager, Saunders-Roe, Limited*) said that he had spent 25 years in the industry—the first 10 on design, the second 10 on production, and the last five watching both. He felt that the fault—if fault there was—was partly that of the management of some companies and not so much that of the individual departments.

Somewhere around 1943, emphasis began to be placed on the importance of the Design Department having men with good theoretical backgrounds—men with degrees—but the shops had not yet got to such a position. By 'shops', Mr. Browning meant the staff concerned with planning production, production methods, and so on. If the engineering staff was to achieve its proper position, it required equally qualified men in the key jobs and it was a management responsibility to see that salaries were sufficiently attractive to encourage such men. By doing this, he felt sure that each department would have a better understanding of the others' problems.

Mr. H. R. Watson (*Chief Designer, Sir W. G. Armstrong Whitworth Aircraft Co. Ltd.*) said that a good deal of time had been spent in deciding where the fault lay; the design people said that the production people were no good, and *vice versa*, in front of their customers. There seemed to be a grave danger that their customers might believe both of them.

The supersonic aircraft with which they were all struggling now were producing a number of problems, and in particular there was the fact that as the wings became thinner, the coverings became thicker. The old practice of taking a piece of 18-gauge sheet, laying it round the wings and getting it to the right shape had disappeared. New and thicker flanges had to be made and Dr. Russell had described some ways of doing it. New machinery had to be devised, and the design and production departments were working on the problem together. They had not reached a solution yet, but at least they were trying.

Mr. T. Gilbertson (*Director and General Manager, Folland Aircraft Ltd.*) expressed the opinion that at the present meeting no one had yet hit on the real culprit; in his view, it was the Ministry of Supply.

His strong belief was that the machine tool industry was not geared up to the aircraft industry, and some of the faults lay in that direction. His own Company were still waiting for a machine which had been ordered two and a half years ago, and he believed that they had been the first in the field to want it. He had been to several machine tool firms to try and buy machines and had been told that he must wait his turn in spite of any priority, because of the export instructions given by the Government, and in spite of the fact that to buy a certain machine tool here the price might be about £3,000, while to buy it from America might cost £9,000. The delay in production at the present time through lack of these fine machines was a direct consequence of adopting the wrong policy a year or two ago.

The prototypes which had been evolved were proof that there was nothing wrong with the designers of this country, neither was there anything wrong with the skill of the British Production Engineer. The horse-power required per pound weight of aircraft had gone up about 10 times since before the War. Figures to that effect had been published in *The American Machinist*. No comparison could be made with the motor trade—it was a separate problem peculiar to the aircraft industry.

To make any progress, more practical support must be forthcoming from the Ministry of Supply, together with more financial help, because no large firm—let alone a firm of moderate size—could stand the cost of ordering some of these expensive machine tools. Such help from the Government would be better than a great deal of talk about developing the skill of the Production Engineer and the Designer. It was not tackling the problem just to say who was wrong. Design and production were willing to get together, as the experience of Mr. Walker's firm had shown.

Mr. Walker thought that there was a danger of getting huge, expensive machine tools and then having the designers looking round trying to find some use for them. When abroad last year, he had seen a great Plano-miller, which cost a very large sum of money, with flashing lights and hydraulic and electrical gear, machining from 16-gauge at one end to 20-gauge at the other. A massive stretch press was pulling a piece of 18-gauge skin round itself in single curvature. It appeared as though these machines were being employed to find something for them to do. It should not be necessary to machine skin down from 16- to 20-gauge. There was a danger of running into a number of complications in design through the desire to use these machine tools.

Mr. A. A. Jacobsen (*Works Manager, Normalair, Ltd.*) asked Dr. Russell and Mr. Walker whether there was any problem which they had put to Production Engineers at their works without getting the answer. Had, in fact, the Production Engineers failed to find a practical solution, in the long run, to any specific problem ?

Mr. Walker gave what he described as a qualified answer. In the main, he said, it was 'No'; if it was 'Yes', by a little get-together it had always been possible to find some solution.

Dr. Russell said that the system in his own Company worked very well, but could be improved by making the Production Development Engineering Department still larger. That Department had no direct responsibility for design or for production, but it formed a link between the two. The trouble often was that the Production Engineer was fully occupied by his immediate problems, which very often overwhelmed him, while the designer might need to look 10 years ahead.

There was a gap that had to be filled. The Production Development Engineer should have experience on design as well as production, and he should have a properly qualified team working with him. He should also get suitable contracts from the Ministry of Supply. It was his job to explore new processes which were merely ideas, not sufficiently developed to justify the designer in putting them on a drawing, and too radical to expect the Production Engineer to take them as they were and use them in production.

There was much to be said for a subsidiary link between that department and the design staff. Unlike Mr. Walker, he believed in a structures designer, a man on the design staff who had no direct responsibility for stress calculations and so on, but whose job it was to get the design efficient and simple, and to guide the draughtsman on details.

The suggestion had been made that the planning engineer should be on a level with the draughtsman. He would like the planning engineer to be better than the average draughtsman. The jig designer has usually enough status, and neither the planning engineer nor the jig designer was sufficiently qualified.

The problem in future would become even more marked, because the whole educational system of the country was designed to segregate boys at the age of eleven and to push some into grammar schools and others into technical secondary schools. The grammar schools sent their bright boys to the universities and unless, in the future, the production side took some of these, they would get only second-best people. They had to tap that source.

THE CHAIRMAN said he did not propose to sum up, but would like to say that he found his students wanted to go into one of three avenues, and they were fairly evenly divided between them. One was design and research, the second was production, and the third was Canada.

From now on, a much greater wastage might be expected and it should be planned for now rather than in three years' time, when the position would be very difficult.

This Report of the Proceedings of the Southern Section Conference will be concluded in the April issue of the Journal.

WORK STUDY TRAINING IN THE WEST OF ENGLAND

FOLLOWING the announcement in the February, 1953, Journal, that the Institution of Production Engineers is giving active assistance in the establishment of the School of Work Study at the College of Aeronautics, Cranfield, it is interesting to note that a well-known member of the Birmingham Section has been appointed Head of a new Department of Work Study, opened at Bristol last month.

He is Mr. G. P. Wade, B.Sc., M.I.Prod.E., A.M.I.E.E., A.M.I.I.A., who was trained at Metropolitan Vickers Electrical Co. Ltd., and has for the last four years been responsible for Work Study Training in the Industrial Administration Department of the Birmingham College of Technology.

Mr. G. P. Wade

Mr. Wade's assistant at Bristol, Mr. G. R. Burn, is an Associate Member of the Institution, and until recently was Chief Work Study Engineer at Hoover, Ltd., High Wycombe.

The new Department has been set up by the Engineering and Allied Employers' West of England Association at the request of its member firms, in order to assist in their efforts to achieve greater efficiency and higher productivity. This is an entirely new development in the engineering industry, for no employers' organisation has hitherto embarked on such a project.

The first task of the new Department is to organise training courses in Work Study for those responsible for the planning of manufacturing methods and the fixing of piecework rates, to give them an opportunity of ensuring that they are fully informed of the latest techniques of Motion Study, Time Study, Job Evaluation, and Incentives. Thorough training and practice in Time Study will be given to those who need it and, as many firms in the area are engaged in jobbing and small batch production, attention will be directed to methods of compiling standard data from which operation times can be predetermined.

A two-day Work Study Conference is being held on 4th/5th March, 1953, at the Department's Headquarters in Brunel House, St. George's Road, Bristol, where management representatives from firms sending men for Work Study training will be given a review of the subject, with particular reference to the ways in which management can support and make use of a Work Study Department.

The first full training course commences on 9th March, 1953, and lasts for eight weeks. The first four weeks are spent in full-time instruction and practice at Brunel House; the student then returns to his own factory for a fortnight to put into practice what he has learned, during which period he is visited by members of the teaching staff; and the final two weeks are spent at Brunel House to consolidate the training.

Mr. G. R. Burn

The course, which is residential, is restricted to 10 students, and it is proposed to hold four courses during the current year. The fee for tuition is 90 guineas.

Short courses for foremen will be held as the need arises, and it is probable that courses concentrating more especially on Motion Study and Method Improvement will be called for when the immediate demand for better standards of work measurement has been satisfied.

NEWS OF MEMBERS

MR. WALTER PUCKEY

Mr. Walter Puckey, Deputy Controller of Supplies (Aircraft Production), Ministry of Supply, and a Vice-President of the Institution, left the United Kingdom recently with a Mission to Australia.

The Mission is concerned largely with defence problems in the field of aircraft development and production.

MR. H. TEASDALE

Mr. H. Teasdale, B.Sc., Member, has recently taken up an appointment as Education and Training Officer with the North Western Gas Board.

Mr. Teasdale is well known to many members of the Institution for his invaluable work as Hon. Secretary of the Yorkshire Section, when he was Education Officer at John Lund & Company, Ltd., Keighley.

Prior to his new appointment, Mr. Teasdale was Education Officer to the Engines Division of the Bristol Aeroplane Company, Ltd., and during that period was a very active member of the Western Section Committee.

MR. A. D. LIDDERDALE

Mr. A. D. Lidderdale, Member, has been appointed Chief Mechanical Engineer to The Telegraph Construction & Maintenance Company, Ltd., with responsibility for the management of the Engineering Department.

Mr. Lidderdale, who served his apprenticeship with Leyland Motors, Ltd., remained with that firm until the outbreak of World War II, when he joined the Army, attaining the rank of Lieut.-Colonel, R.E.M.E. He was subsequently appointed Assistant Director of Tank Design.

NEW APPOINTMENTS

Mr. E. R. Cash, Associate Member, has been appointed Assistant Works Manager for A.E.C. Ltd., Southall.

Mr. G. A. Daniell, Associate Member, has been appointed a Director of Production Tool & Gauge (Lowestoft) Ltd., Lowestoft.

Mr. A. D. Copland, Associate Member, is now Apprentice Supervisor in Liverpool to The English Electric Co., and D. Napier & Sons, Ltd.

Mr. D. E. Graham, Associate Member, has joined the staff of Associated Industrial Consultants, Ltd., London.

Mr. F. V. McGuire, Associate Member, is now with Joseph Lucas (Gas Turbine Equipment) Ltd., as Design Engineer.

Mr. R. Thomson, Associate Member, is now Plant Engineer with Brookhirst Switchgear, Ltd., Chester.

Muhammed Amir, Graduate, has been appointed Technical Sales Engineer with William Jacks & Co. Ltd., Karachi.

Mr. J. C. Amos, Graduate, has been appointed Cost Liaison Officer for C. A. V., Ltd., London.

Mr. W. Bailes, Graduate, has recently gone into business on his own account, as The Bradford Design & Drafting Agency, Baildon.

Mr. J. M. Barber, Graduate, is now Production Engineer to The British Electric Resistance Co. Ltd., Ponders End, Middlesex.

Mr. A. E. Clarke, Graduate, has recently been appointed Assistant Manager (Production) of the Valve Department of Guest, Keen & Nettlefold (Midlands) Ltd., Darlaston.

Mr. J. L. Dryden, Graduate, is shortly taking a post as Work Study Engineer with Thorneloe & Clarkson, Ltd., Leicester.

Mr. D. J. I. Gray, Graduate, is now Assistant Standards & Quality Engineer with the Marshall-Fowler Organisation of Gainsborough and Leeds.

Mrr. M. R. Harvey, Graduate, has taken an appointment as Works Manager of Surplice & Tozer, Ltd., Windsor.

Mr. Brian Lee, Graduate, has taken up an appointment as Research Engineer with The Production Engineering Research Association of Great Britain, Melton Mowbray, Leicestershire.

Mr. K. L. Morgan, Graduate, is now employed as a Development Engineer at Stewart & Lloyds, Ltd., Bilston.

Mr. J. B. Murphy, Graduate, is a Planning & Methods Engineer with The de Havilland Aircraft (Canada) Pty, Toronto.

Mr. S. A. Onions, Graduate, has been appointed Planning Engineer at Bristol Aeroplane Co. Ltd., Engine Division, Bristol.

Mr. J. J. Peck, Graduate, has been appointed Personal Assistant, with responsibility for planning and time study, to the General Manager of Hopkinson Electric Co. Ltd., Cardiff.

Mr. G. R. Ridgway, Graduate, has taken a position as a Designer in the Chocolate and Confectionery Section of Baker, Perkins, Ltd., Peterborough.

INSTITUTION NOTES

INSTITUTION CONFERENCE, HARROGATE

As already announced an Institution Conference will be held at The Royal Hall, Harrogate, from 25th/28th June, 1953. The arrangements and programme planning will be similar to the Conference which was held at Harrogate in June, 1951, and full details will be published later.

Members are asked to notify the Secretary as soon as possible if it is their intention to attend the Conference. Application forms may be obtained from Section Hon. Secretaries or from Head Office. A list of Harrogate hotels will be sent to all members on application to the Secretary, and early reservation of accommodation is advised. The Institution Headquarters for the period of the Conference will be at the Hotel Majestic.

Conference charges are as follows:

Members' Conference Fee -	30/-
Gentlemen Guests Fee - -	30/-
Lady Guests Fee - - - -	10/-
Conference Banquet Tickets -	25/-

MEETING OF COUNCIL, JANUARY, 1953

A report of the recent Meeting of Council, together with a report of the Annual General Meeting, will appear in the April issue of the Journal.

CALCUTTA SECTION DINNER

The first Dinner of the Calcutta Section since its inception in 1946 was held on 13th December, 1952, at the Great Eastern Hotel, Calcutta, and was an extremely enjoyable and successful function.

The Guest of Honour was Sir Jnan Chandra Ghosh, Director of the Indian Institute of Technology, Kharagpur, and among the many well-known personalities present were Dr. S. R. Sen Gupta, Principal of the Bengal Engineering College; Professor G. A. Robinson; and Professor T. U. Matthew, of the University of Birmingham, who was visiting India as Head of a United Nations Mission.

The toast to "The President, Republic of India", was proposed by Colonel C. Warren-Boulton, who referred to the invaluable work done by Mr. J. D. Scaife in establishing the Institution of Production Engineers in India.

The President of the Calcutta Section, Mr. J. D. Mookherjee, then proposed a toast to the guests, to which Sir Jnan Chandra Ghosh replied, expressing appreciation of the work being done by Production Engineers in India towards decreasing the present high cost of living.

In view of the success of the Dinner, the Calcutta Section hopes to make it an annual event.

Sir Jnan Chandra Ghosh replying to the toast of "The Guests" at the Calcutta Section Dinner. From the left are Mr. J. Warren-Boulton (Section Hon. Secretary); Professor T. U. Matthew, M.I.Prod.E.; Sir Jnan Chandra Ghosh; Mr. J. D. Mookherjee (Section President); Dr. T. Sen; Professor G. A. Robinson; Colonel C. Warren-Boulton.

In the centre of the front row of this group, photographed during the London Section visit, is Mr. E. S. Waddington, of Philips Electrical, Ltd., with Mr. R. Hutcheson, London Section Hon. Secretary, on his left. On the extreme left of the front row is Mr. J. E. Burnett, Member of Council, and a member of the London Section Committee.

LONDON SECTION WORKS VISIT

On 20th January last, a large party of members of the London Section was entertained to lunch by Mr. E. S. Waddington, of Philips Electrical, Ltd., and subsequently visited the Company's Application Showrooms at Brixton Hill.

At the Showrooms, which are devoted to the activities of the Company's Industrial Group, demonstrations were given of the latest developments in equipment for increasing production in the engineering field. Resistance and arc welding form an important branch of the Group's work, together with the application of high frequency electric current, and demonstrations were given of induction and dielectric heating.

Magnetic filtration, especially as applied to the collection of swarf from grinders and the purification of grinder coolants, attracted considerable interest.

The Instrumentation Section covers a wide field, including stroboscopic equipment for the examination of high speed machinery under normal working conditions, strain gauging apparatus, and a surface finish inspection instrument intended for workshop use.

GRADUATES — EXAMINATION REQUIREMENTS FOR ASSOCIATE MEMBERSHIP

All Graduates who completely satisfied the Graduateship Examination requirements, or gained complete exemption from them, before the 1st September, 1950, and were elected Graduates or made application for election before that date, may be deemed to have satisfied the examination requirements of the Institution in all respects.

The above ruling was given at a meeting of the Council held in January, 1949, and it means that Graduates covered by this ruling may not be asked to undertake any other examination or part of an examination when they apply for transfer to the grade of Associate Member.

The ruling does not apply to those Graduates whose application for election to that grade was submitted after the 1st September, 1950.

HAZLETON MEMORIAL LIBRARY

Members are asked to note that the Library will be open between 10 a.m. and 5.30 p.m., from Monday to Friday each week. After 28th March, 1953, the Library will *not* be open on Saturday mornings. Due to Meetings, the full facilities will not be available at the following times during this month:

Tuesday, 10th March, from 2.30 p m. — Wednesday, 11th March, from 2.30 p.m.
Thursday, 12th March, all day. — Tuesday, 31st March, from midday.

It would be helpful if, in addition to the title, the author's name and the classification number could be quoted when borrowing books.

REVIEWS

657.47 COST ACCOUNTING

"Cost Accounting in Industrial Management" by Harry Fisher and David L. Thompson. *London, Gee & Co.*, 1952. 210 *pages.* 21s.

The scope of this book is to show several particular methods of costing, so that the reader can adopt or adapt the ideas and plans illustrated according to personal interests. It is essentially a practical book and the systems which are outlined are those in operation in a number of different industries.

The book gives a clear and constructive treatment of problems of selling price determination, gross profit, margin control, standard costs and budgetary control and handling of process and departmental costs. The book also deals with the use of rationalised calendar, expense and material codes, and gives formulæ for the control of work in progress and ascertainment of manufacturing cycles.

Two complete accounting schemes, together with specimen routines and forms, are included in the book, which emphasises the important contribution which cost accounting can make to efficient industrial management. N.R.T.

Q331.2 CLERICAL SALARIES ANALYSIS 1952:

Office Management Association, London. 70 *pages. Price* 25/-.

This Report, which is the latest in a series of biennial Reports made by the Association on this subject, gives the statistical results of the nation-wide survey of clerical salaries carried out on the 1st March last. It contains an analytical report by Mr. O. G. Pickard, B.Sc.(Econ.), of the North-Western Polytechnic, London, on the main trends that these statistics reveal. The work is an invaluable guide for all those who are concerned with salary rates for clerical staff in private industry and commerce and, as previously, tables are given to show a comparison with the salary rates of employees in Public Offices, Nationalised Industries, etc. Coming, as it does, it provides first-hand evidence of the numerous changes, regional and national, which have taken place during the last two years, and which hitherto have not been able to be regarded in their proper perspective. S.C.

331.124

"Foremanship" by F. J. Burns Morton. *Chapman and Hall Limited, London.* 316 *pages.* 25/-.

The preface notes that "The Foreman in British industry has had little opportunity of enlarging his knowledge of general supervisory practice." This text book is intended as an aid to the organisation of courses of instruction for foremen and supervisors. It provides a comprehensive survey of the many aspects of foremanship and details the techniques used in industry with which the foreman needs to be familiar.

Nearly all reports of the Anglo-American Productivity Council Teams have emphasised the important part played by American foremen in increasing efficiency by making ideas work, by providing initiative, and striving for better methods. The efficiency of British supervision can be raised by efficient training and Mr. Burns Morton has gathered together all the relevant points to be considered when considering this training.

The book is in three parts, Direction—Control—Personnel.

In Part I the chapter "Supervision" sets out the duties and responsibilities of foremen whilst the chapters on "Organisation" and "Managemnt" deal with the application of these subjects at both work-shop and factory level. They give clear and concise definitions, and describe the foreman's responsibility for good organisation, and his part in management.

Part II includes chapters upon "Operation Control"—"Production Control"—"Quality Control"—"Cost Control." The foremen is in continuous contact with these specialist techniques and needs to know something of their application on the factory floor. The chapters on these control subjects give him a clear idea of these subjects and of their importance to him in achieving efficient control of his department.

Part III on Personnel includes chapters on "Training" — "Incentives" — "Leadership" — "Labour Management" and "Working Conditions." One of the main duties of foremen is to instruct others and the chapter devoted to training details this subject very thoroughly.

The foreman is constantly concerned with incentives and the effects of incentives schemes; the chapter under this heading defines incentives, and deals with Rate-setting, Time-work, Wages Levels, and Incentive Plans.

The chapters on "Labour Management"—"Working Conditions" and "Leadership" give, in detail, ways and means of ensuring that foremen are well informed and are capable of achieving results through the people working for them.

Included in an Appendix are some useful hints on reading and note-taking and a comprehensive bibliography. A.J.M.

658.2 FACTORIES—*Situation*

"Cost of Industrial Movement: A First Report on the Economics of Establishing Branch Factories," by W. F. Luttrell. *Cabridge, University Press,* 1952. 104 *pages.* 18/- (*National Institute of Economic and Social Research—Occasional Paper No.* 14).

This is the first Report issued as a result of research started early in 1949, and presents some very enlightening information on this subject on which little hitherto has been written. The Report is introduced by a brief discussion of the background causes and associated factors involved in industrial movement.

The second and third Chapters describe methods used to analyse and co-relate the cost figures of different companies. Chapters V and VI give four example analyses in detail. Chapter V deals with three separate branch factories of a shoe manufacturing firm, while Chapter VI analyses an engineering company's branch factory. In each case, a comparison

is made between the production cost at the branch factory compared with the parent factory; the probable cost of increased production by expanding the parent factory; the financial loss to the company if no expansion had been carried out; and in the case of the engineering example, the cost at branch factory compared with the sub-contracting. In concluding the author has drawn on the results of many other investigations in an endeavour to indicate trends.

The author and investigation team are to be congratulated for this fine work and the writer looks forward to the publication of the complete report.

G.C.S.

ABSTRACT

338.9 PRODUCTIVITY

International Labour Organisation—*Metal Trades Committee.* Factors Affecting Productivity in The Metal Trades. *Geneva, I.L.O.*, 1952. 116 *pages.* 4s. 6d.

In essence, this is a summary of many of the salient points raised in the Reports of the various Anglo-American Productivity Teams sent to the U.S.A. by the Metal Trades. It also uses Reports issued by similar teams from Continental Countries.

The level of productivity depends upon a multiplicity of factors many of which centre around labour and its utilisation. While the size of the plant, the degree of standardisation and specialisation will be influenced by the size and nature of the market, Management has a big contribution to make, not only in the attention given to Design, Production, Planning, Cost Control and Research, but in the quality, skill and enthusiasm which it brings.

Proper attention to Material Handling, Layout and Maintenance are all contributory factors, while statistics show that the difference in productivity between European and American workers is also a reflex of the difference in horse-power available per worker.

In the training of workers, particularly as regards apprenticeship and "on the job" instruction, European practice appears to be ahead of American, but in the training of supervision, promotion and upgrading, the reverse is the case.

Time and Motion Study practices can operate to the advantage of the worker as well as Management and every effort should be made to obtain a wider acceptance of these practices in British Industry.

The Report concludes with a reference to hours of work and systems of Wage Payment, the disincentive of high taxation, and a survey of the attitude of Management and Workers to Productivity.

621.3132 DIRECT CURRENT MACHINES

"Direct Current Machines for Control Systems", by A. Tustin. *London, Spon*, 1952. 306 *pages, diags.* £2 10s. 0d.

This book deals with a modern development of the long established direct current dynamo, namely the rotary power amplifier in distinction to the more widely known electronic and magnetic amplification systems. These rotary power amplifiers include metadynes, amplidynes and similar machines and have the advantage of giving a power amplification with an extremely rapid speed of response.

The level at which this subject is dealt with is about honours degree standard, and the book is no doubt intended for electrical engineers and those Production Engineers specialising in the electrical side of machine design.

OTHER ADDITIONS

010 BIBLIOGRAPHIES; CATALOGUES

McColvin, E. R. *ed.* **"Select List of Standard British Scientific and Technical Books compiled at the request of the British Council."** *London, Aslib.* 1952. (4th Ed. Rev. and Enl.) 71 *pages.* 7/6.

070 NEWSPAPERS; THE PRESS

British Provincial Press Productivity Team. **"The Provincial Press: Report of a Productivity Team which visited the U.S.A. in 1951."** *London, Anglo-American Council on Productivity.* 1952. 85 *pages. Illustrated. Diagrams.* 3/6. (Productivity Team Report.)

331.2 WAGES; PAY

Mace, C. A. **"Incentives: Some Experimental Studies."** *London, H.M.S.O.* 1952. [i.e. 1935.] 67 *pages.* 5/6. (Great Britain—*Medical Research Council—Industrial Health Research Board*—Report No. 72.)

331.215 JOB EVALUATION

Matthew, Prof. T. U. **"International Comparison of Job Evaluation: A Preliminary Statistical Analysis."** *Birmingham, University—Department of Engineering Production.* 1951. 15 *pages. Charts.*

Matthew, Prof. T. U. **"Job Evaluation Developments leading to International Use."** *Birmingham, University—Department of Engineering Production.* 1952. 6 *pages.*

331.816 ABSENTEEISM

Behrend, Hilde. **"Absence under Full Employment."** (Limited Ed.) *Birmingham, University—Faculty of Commerce and Social Science-Research Board.* 1951. 137 *pages. Graphs.* 15/-. (University of Birmingham—Studies in Economics and Society—Monograph A 3.)

338.9 PRODUCTIVITY

Anglo-American Council on Productivity. **"Final Report of The Council."** *London, The Council.* 1952. 40 *pages.* 3/6.

Rostas, L. **"Select Bibliography on Productivity."** (Provisional Ed.) *London, Board of Trade.* 1952. 20 *pages.*

338.971 ANALYSIS OF ECONOMIC FLUCTUATIONS AND SITUATIONS

Carter, C. F., *and others.* **"Measurement of Production Movements,"** by C. F. Carter, W. B. Reddaway, R. Stone. *Cambridge, University Press.* 1948. 135 *pages.* 12/6. (University of Cambridge—*Department of Applied Economics*—Monograph No. 1.)

340 LAW

Great Britain—Ministry of Labour and National Service. **"Short Guide to The Factories Acts 1937 and 1948."** *London, H.M.S.O.* 1952. 16 *pages.* 6d.

378.996 TECHNICAL EDUCATION

Joint Committee on Metallurgical Education. **"Education and Training of Metallurgists."** *London, The Committee.* 1952. 56 *pages.*

Lawrence, F. C. **"Training for Management."** *Manchester, Paton, Lawrence & Co.* 1952. 14 *pages.*

389.6 STANDARDISATION

Merritt, H. E. **"Standardisation and Productivity."** *Birmingham, Industrial Administration Group of the Students Union of Birmingham Central Technical College.* 1949. 23 *pages.* 2/-.

514 TRIGONOMETRY

Henry Ford Trade School, Dearborn, Michigan. **"Shop Trigonometry."** *Dearborn, The School.* 1950. 76 *pages. Diagrams.*

536.24 HEAT TRANSFER

Institution of Mechanical Engineers, London. **"Proceedings of the General Discussion on Heat Transfer."** *London, The Institution.* 1952. 496 *pages. Illustrated. Diagrams.* £2 5s.

614.8 PREVENTION OF ACCIDENTS; SAFETY MEASURES

Royal Society for the Prevention of Accidents, London. **"Personal Protective Equipment in Industry: Legal Requirements."** *London, The Society.* 1952. 72 *pages.* 6/6. (Rospa Technical Pamphlet No. 3.)

621.0052 REGULATION AND CONTROL

Minneapolis-Honeywell Regulator Company, Philadelphia. **"Fundamentals of Instrumentation for The Industries."** *Philadelphia, The Company.* 1952. 128 *pages. Illustrated. Diagrams.*

621.357 ELECTRO-DEPOSITION; ELECTRO-PLATING

Electrodepositors' Technical Society, London. **"Journal, vol. 27, 1950-51."** *London, Institute of Metal Finishing.* 1952. 342 *pages. Illustrated. Diagrams.* £2 2s.

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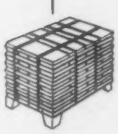

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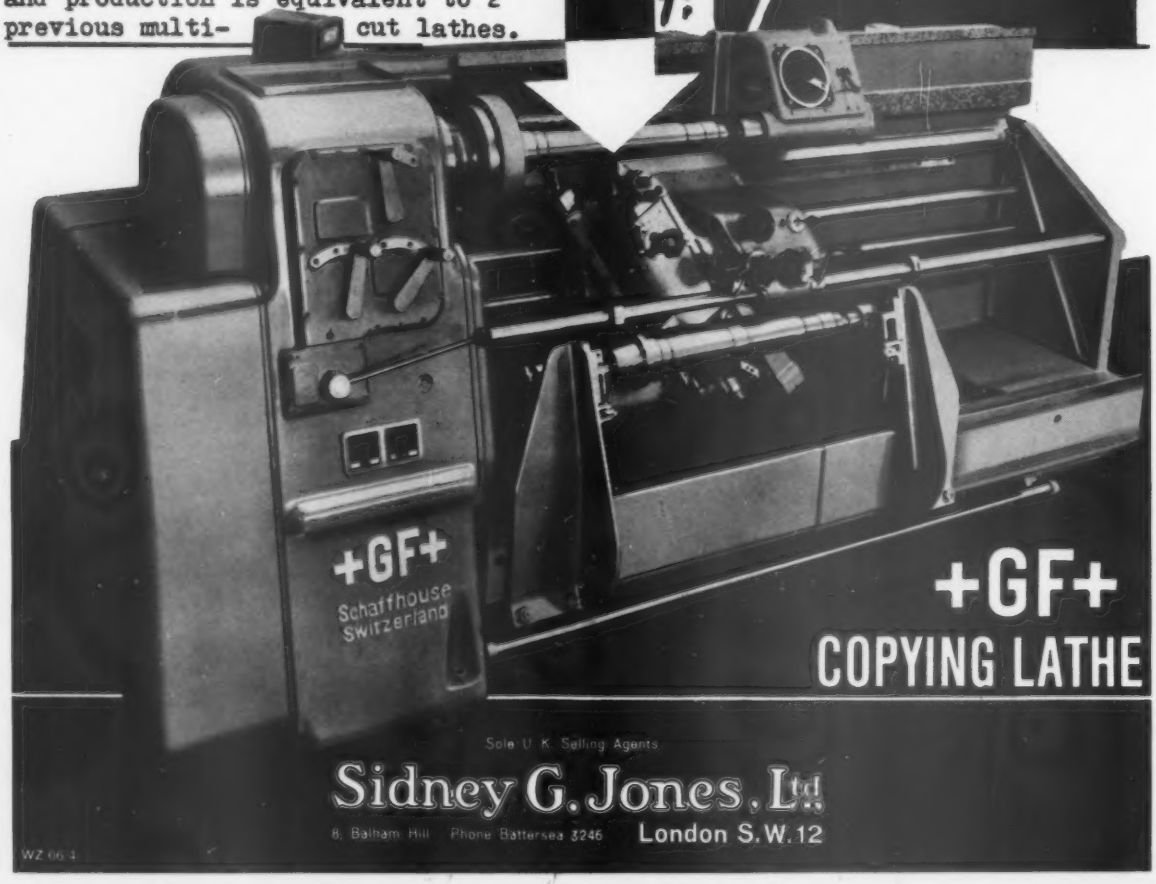

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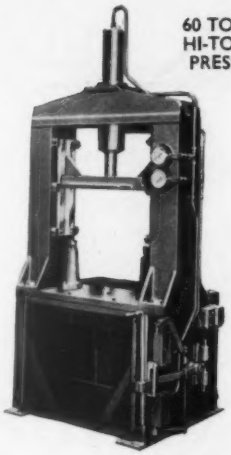

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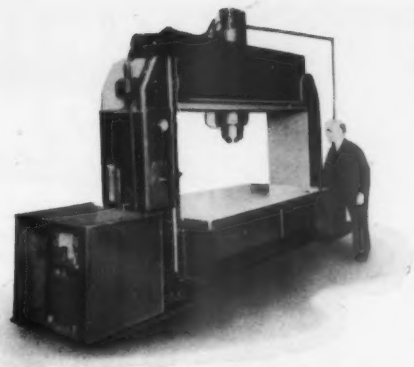

100 TON HI-TON PRESS with power return

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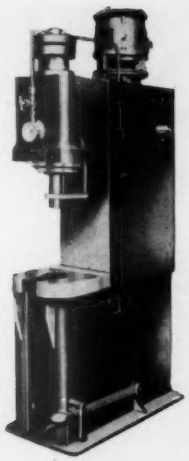

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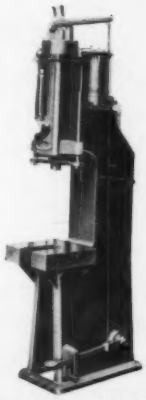

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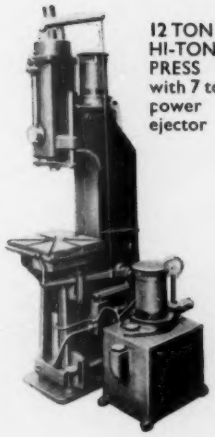

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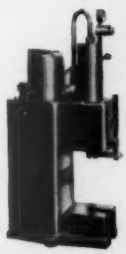

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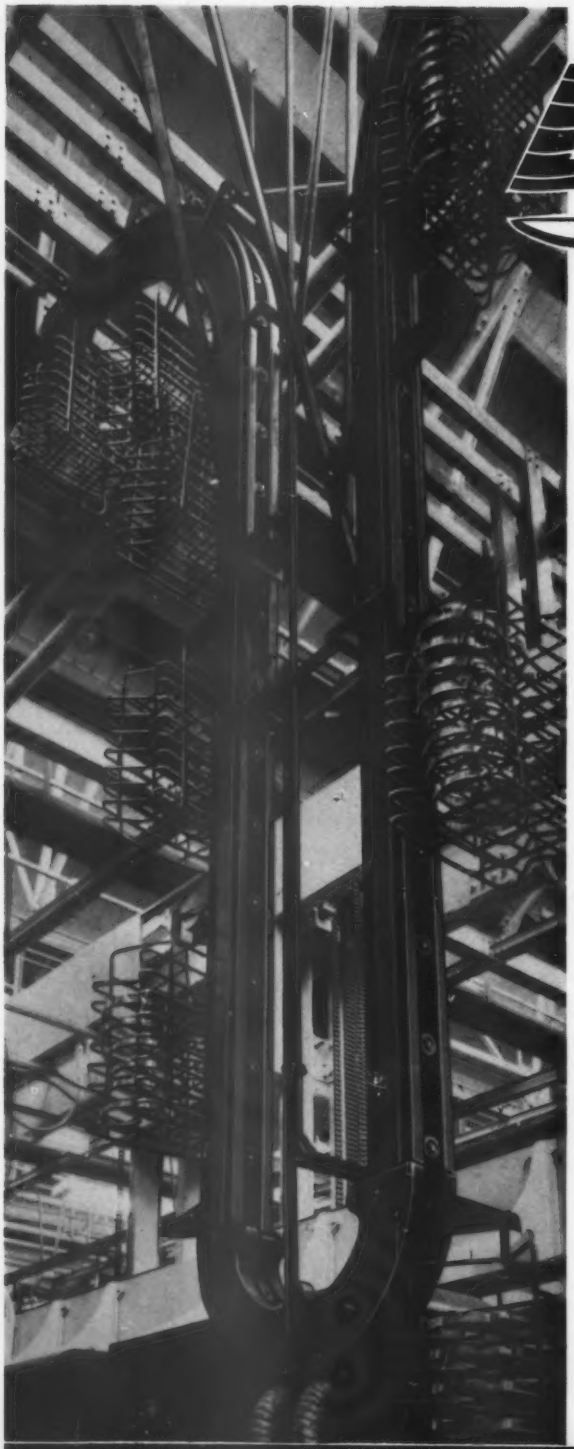

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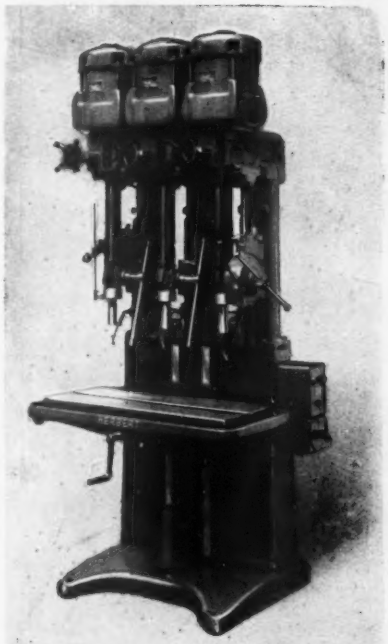

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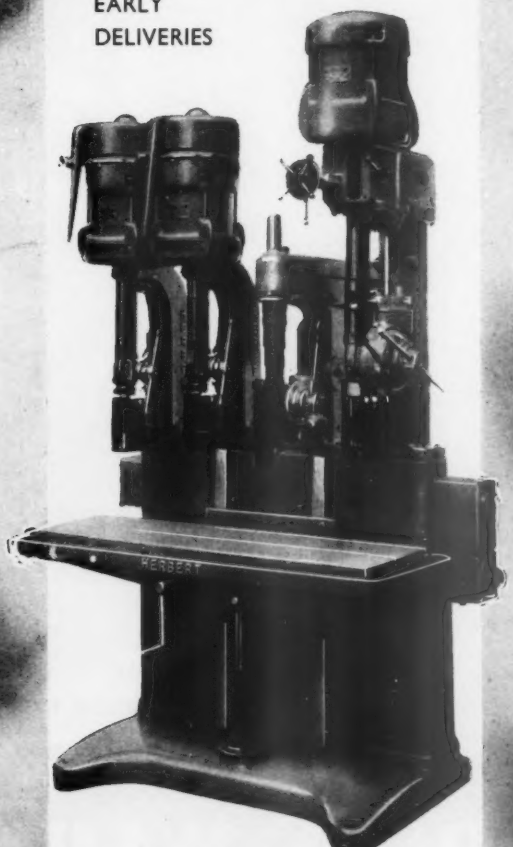

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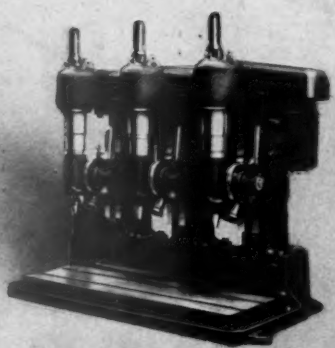

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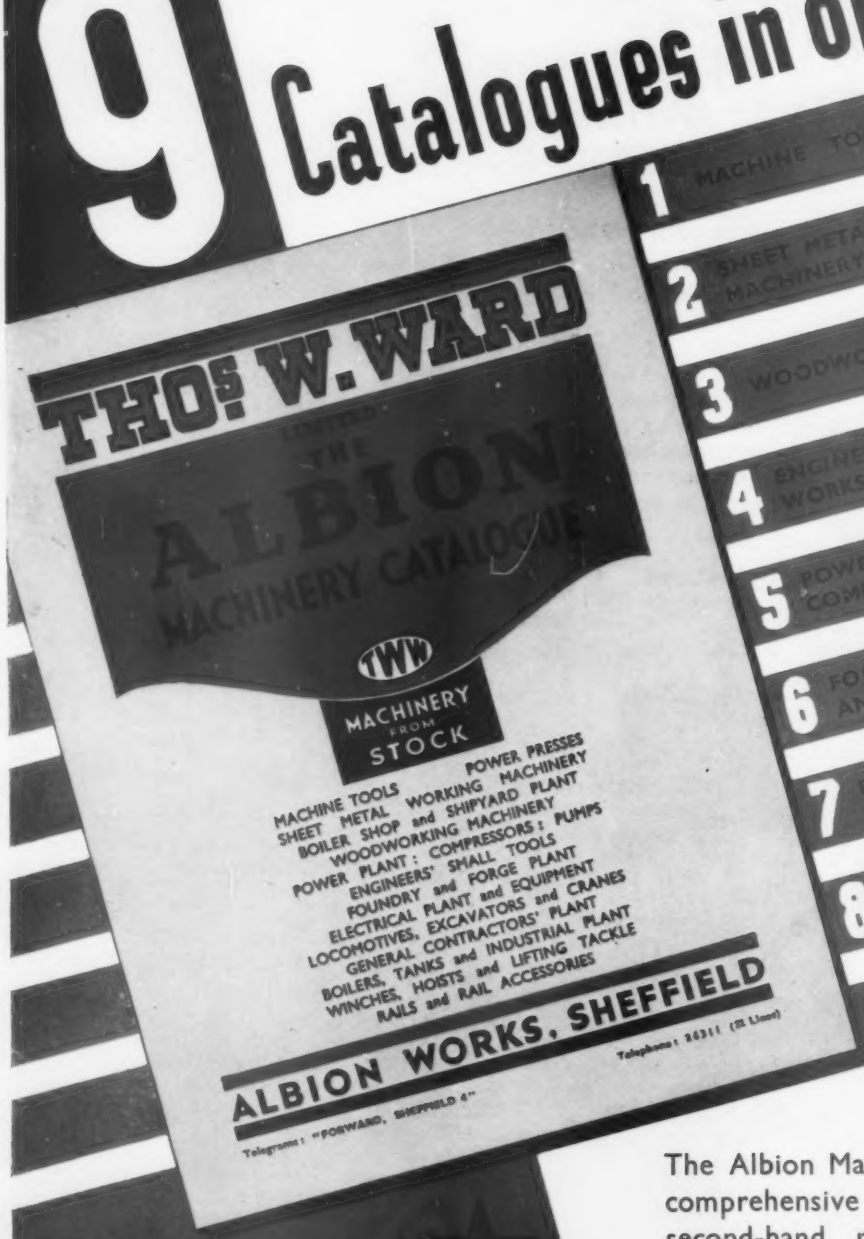

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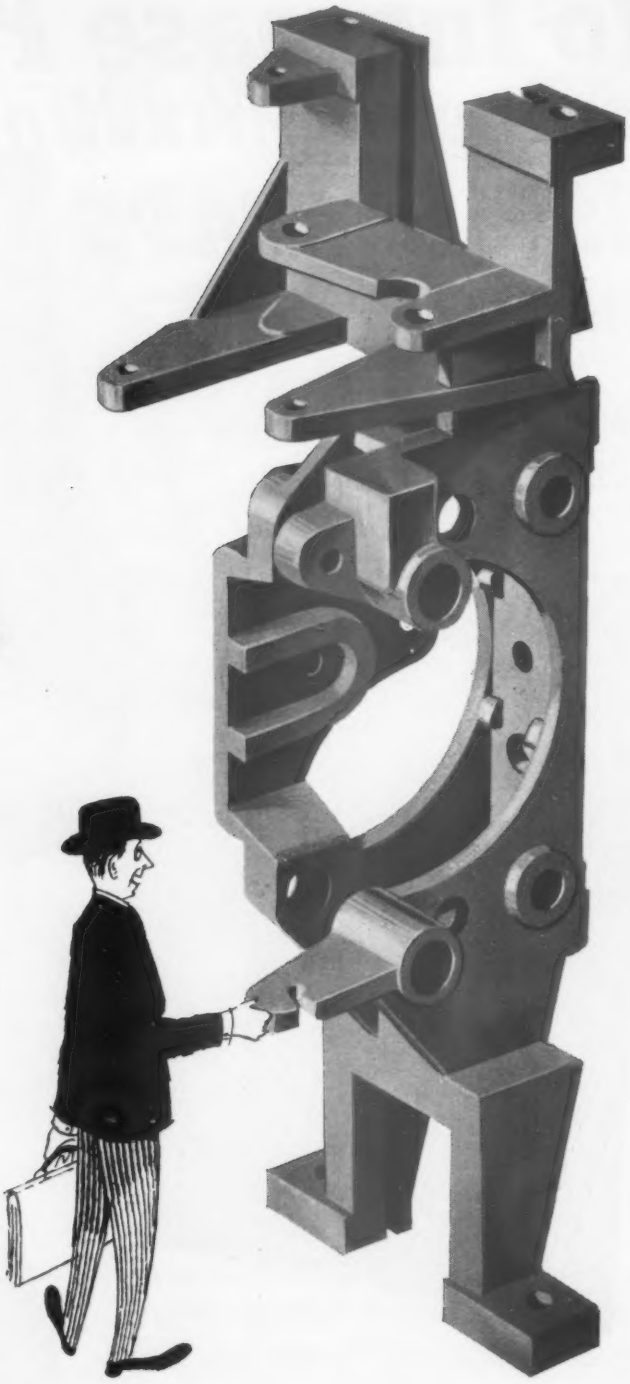

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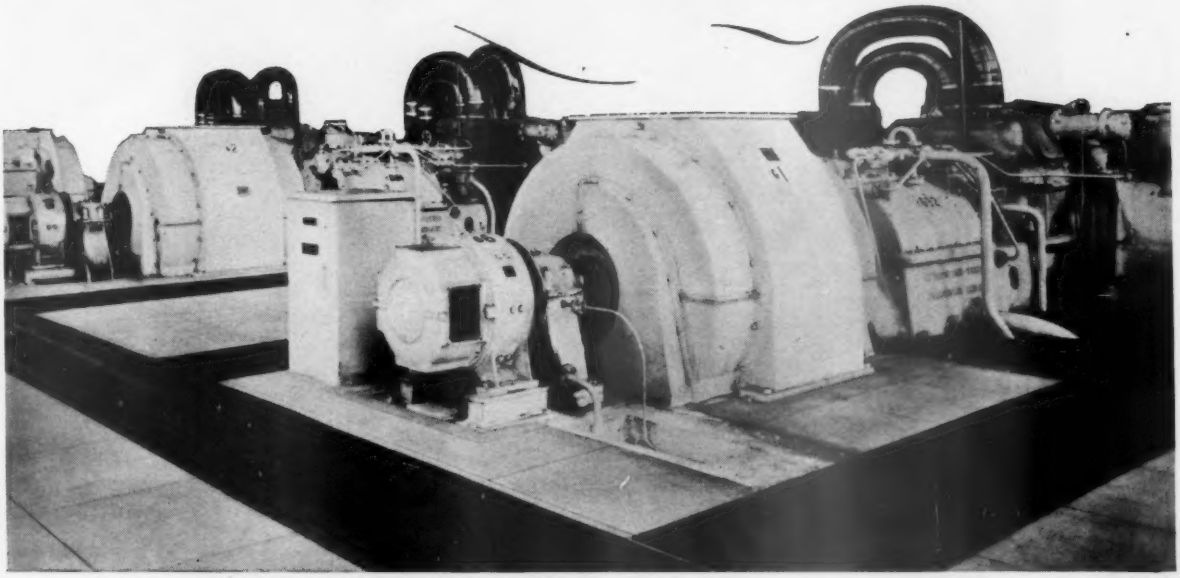

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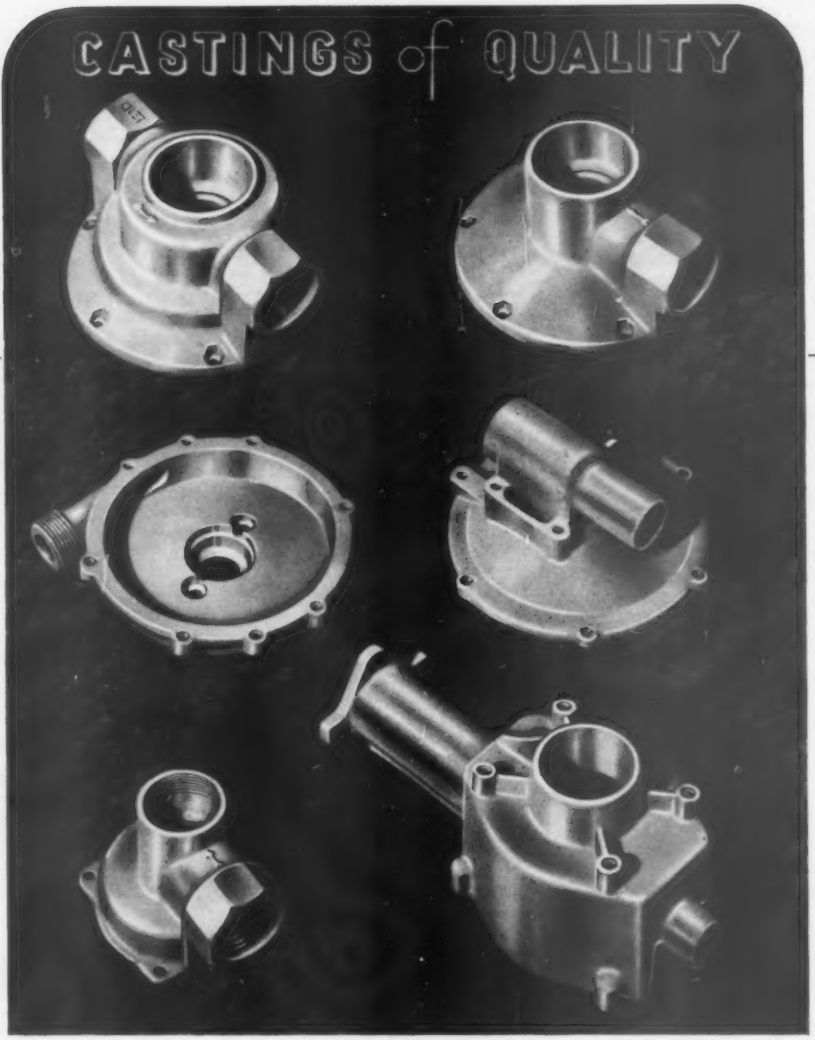

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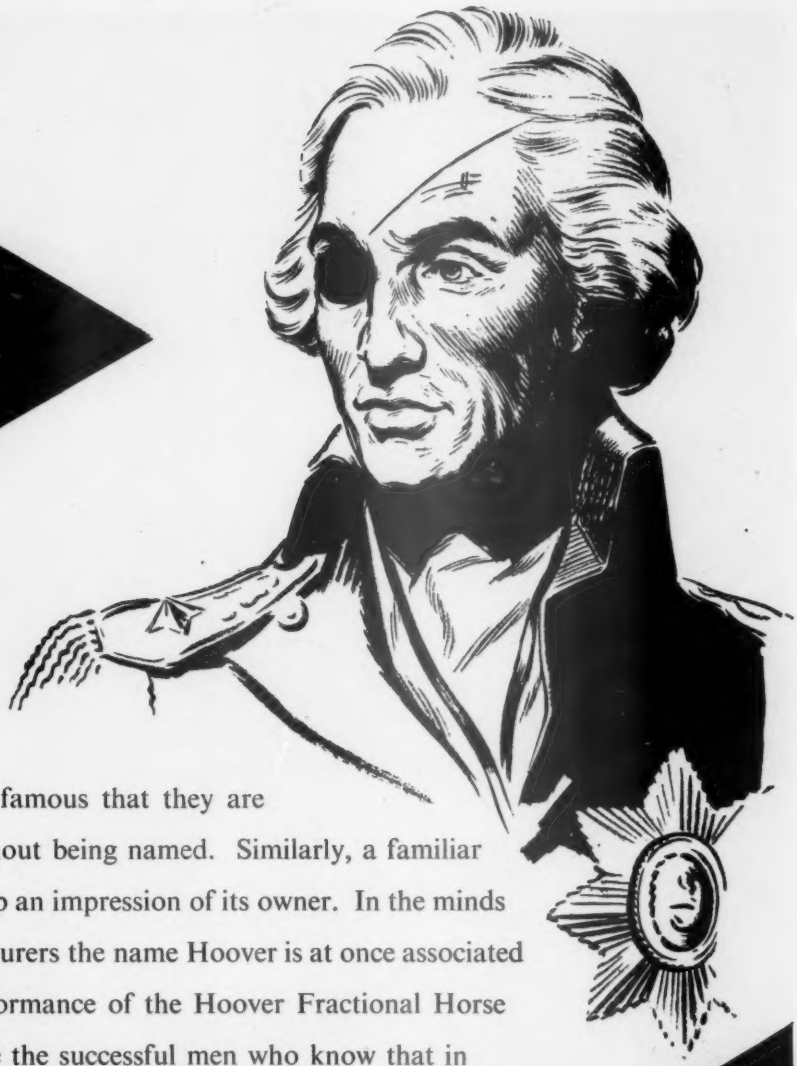

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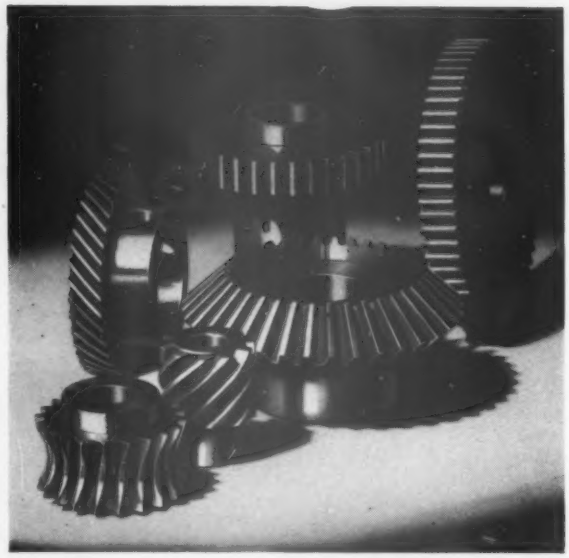

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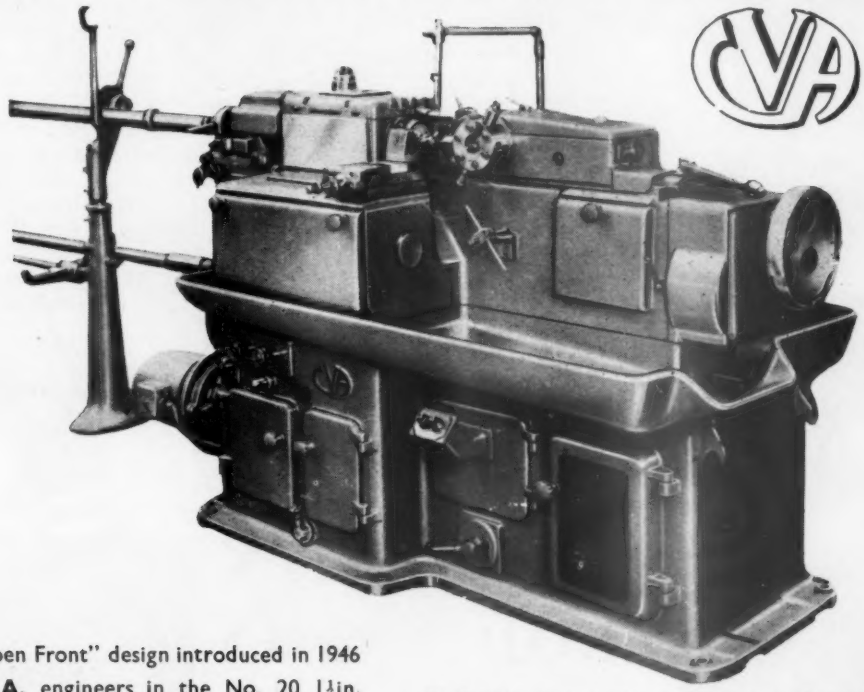

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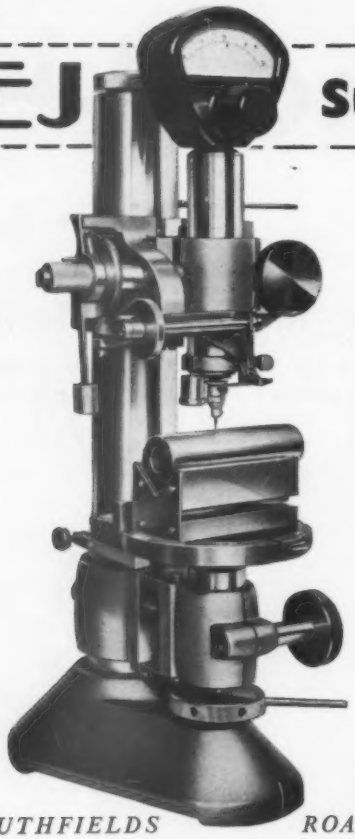

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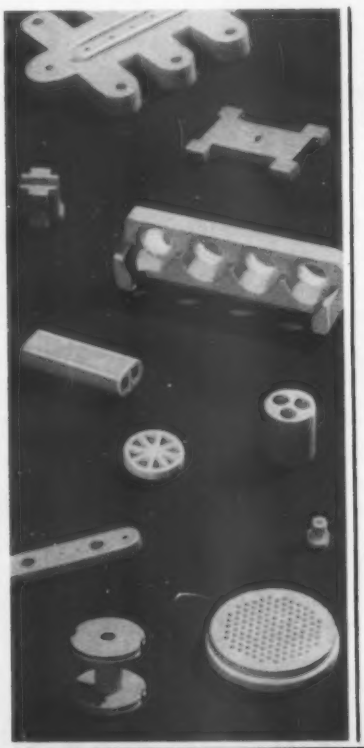

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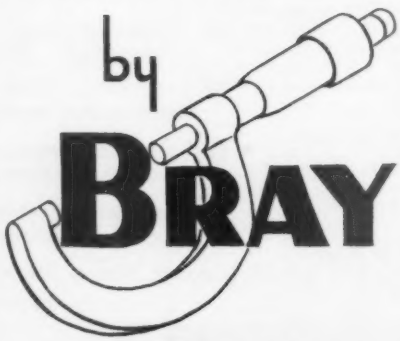

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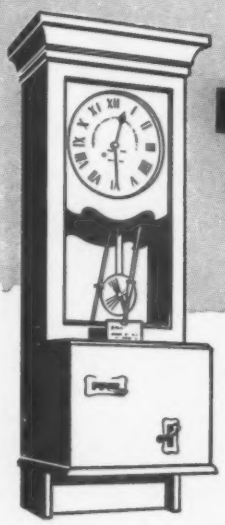

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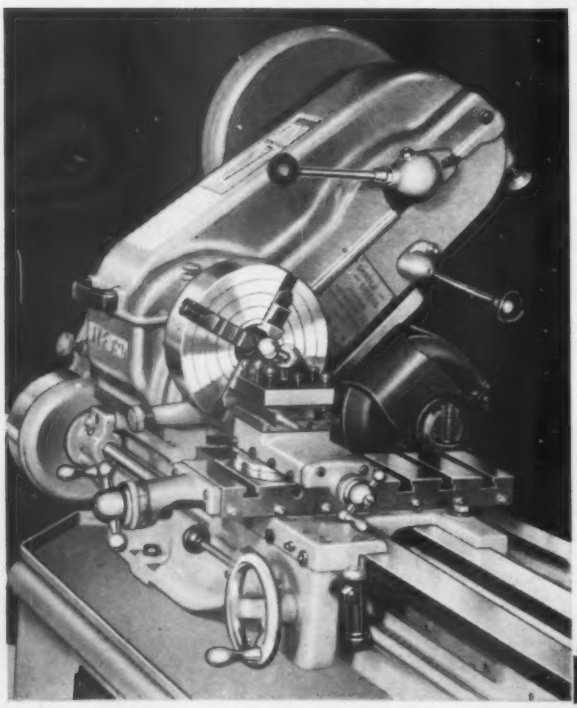

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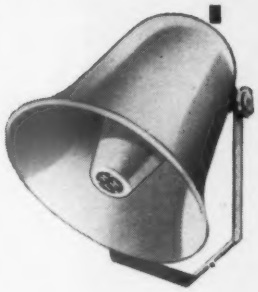

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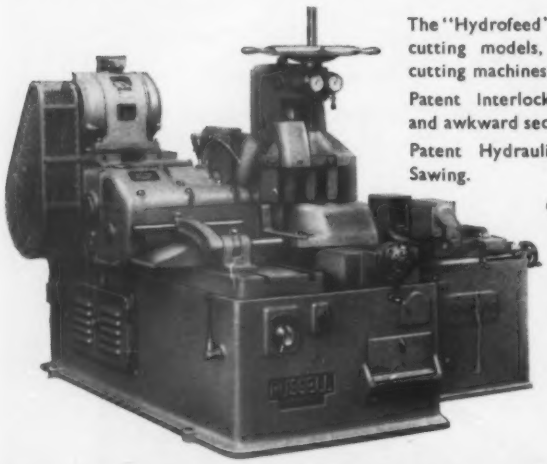

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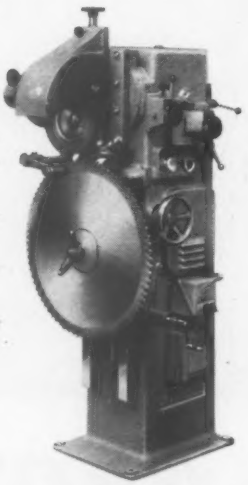

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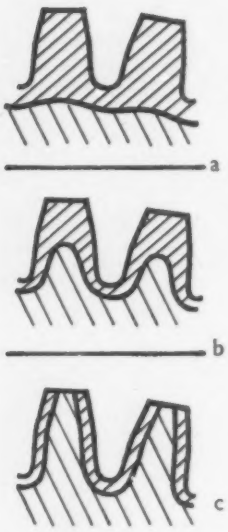
hardening gear teeth



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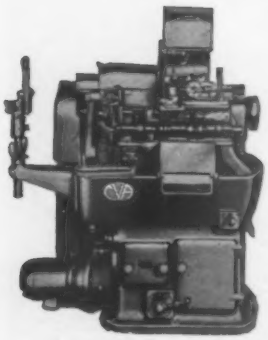

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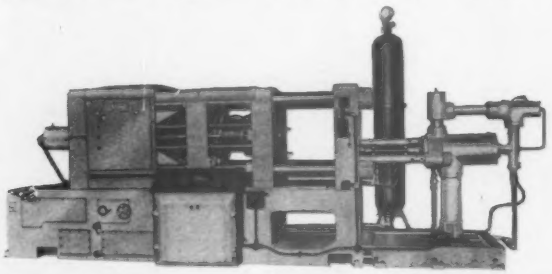

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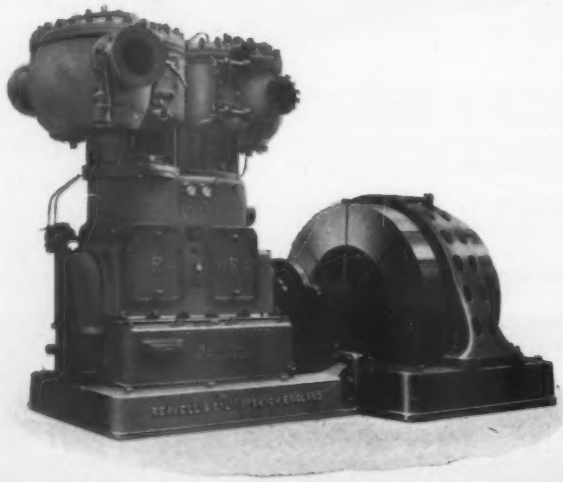

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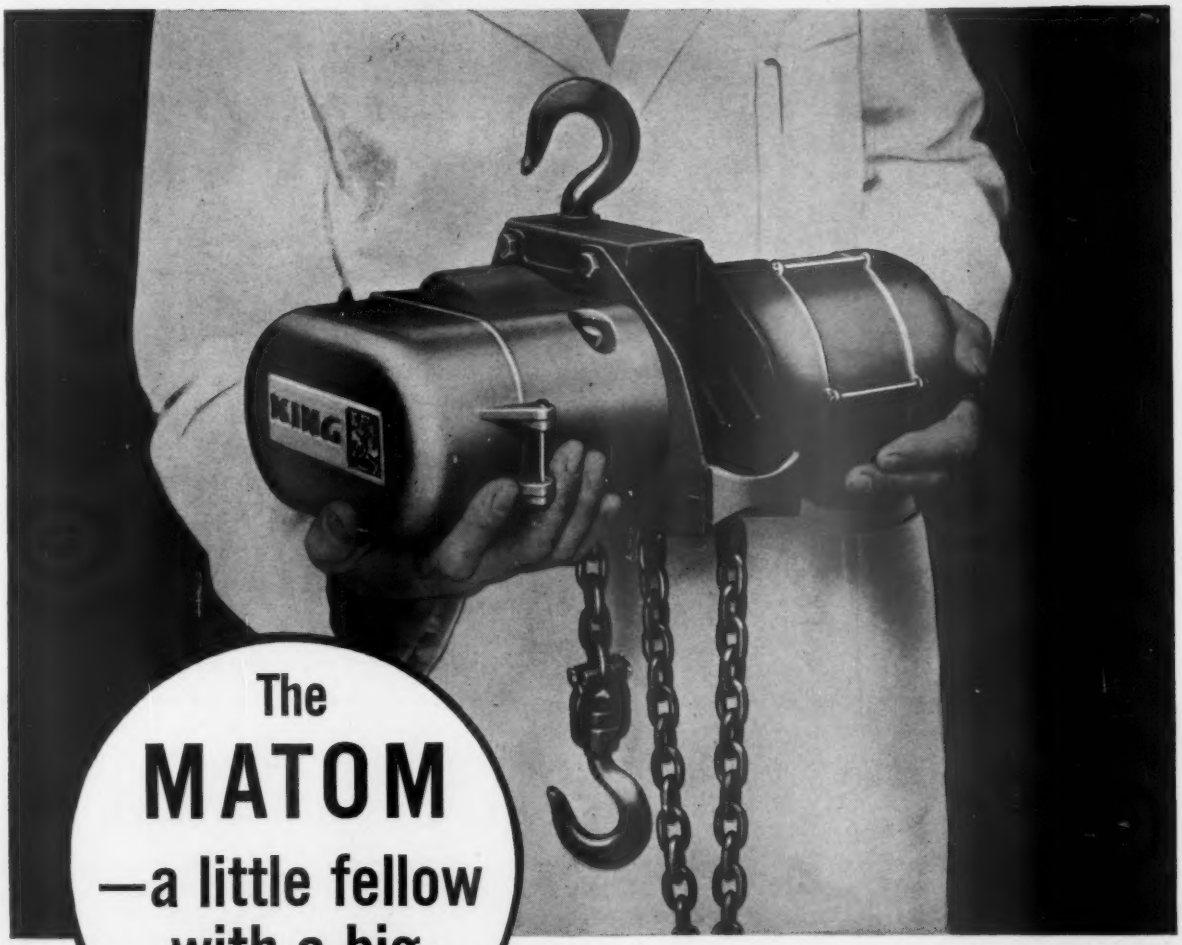

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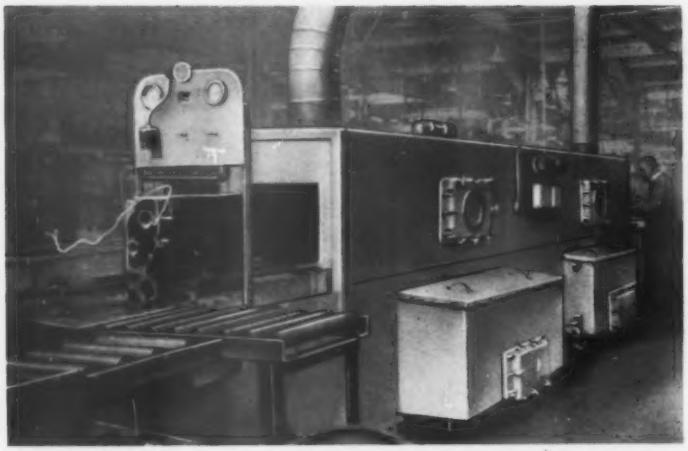

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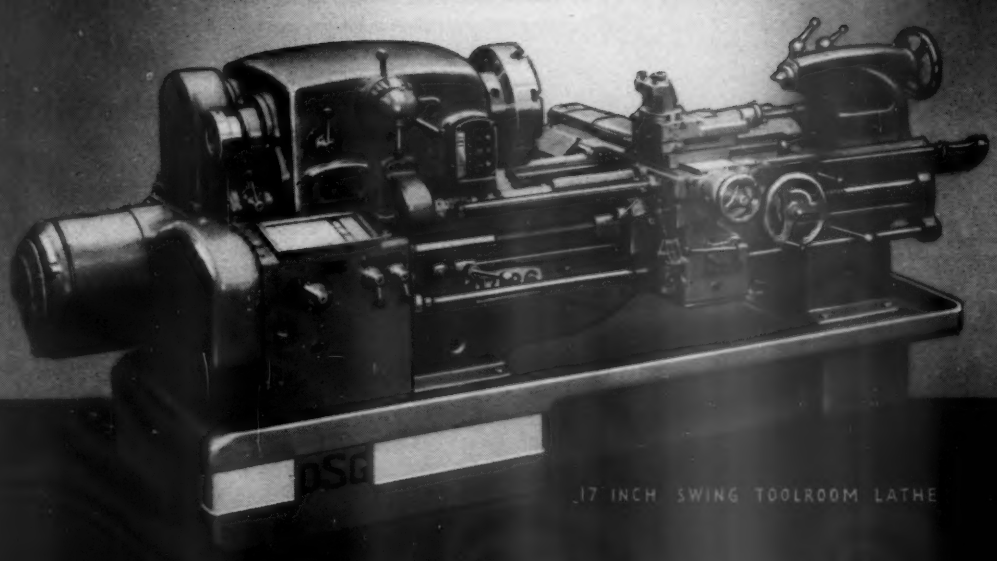

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MODEL SV4D

THE Steinel SV4D Vertical Milling Machine is manufactured from high-grade materials to precision limits. The Vertical Head swivels 45° right and left, and is equipped with handlever and handwheel control for spindle feed. Spindle bored to 3 M.T. has 3·543" (3 35/64") travel whilst reversing switch permits spindle rotation in either direction.

Drive to the spindle from the 2-speed maindrive motor is by means of Vee belts through an intermediate pulley permitting the selection of 12 spindle speeds.

The Steinel Vertical Milling Machine is extremely versatile and suitable for accurately machining a wide variety of components. For high-speed production milling handlever feeds can be supplied for the longitudinal and vertical traverses, together with a table with a working surface 23·62" (23⅝") by 6·889" (6 57/64").

Working surface of table: 24·4" (24 13/32") by 7·784" (7¾").

Length of table: 29·134" (29⅛").

Width of table: 7·784" (7¾").

Longitudinal movement of table (hand and power): 11·811" (11 11/16").

Cross movement of table (hand): 5·9" (5 19/32").

Maximum distance spindle nose to table: 12".

Distance column to centre of spindle: 6·89" (6 57/64").

Travel of spindle quill (hand): 3·54" (3 35/64").

Spindle speeds, Type 1, with standard motor: 71, 112, 189, 280, 450, 710, 1120.

Spindle speeds, Type 2, with pole-change motor: 56, 90, 112, 140, 180, 225, 280, 355, 450, 560, 710, 1120.

Higher spindle speeds optional.

Rates of table feed: ·0063", ·010", ·016", ·020", ·032", ·045".

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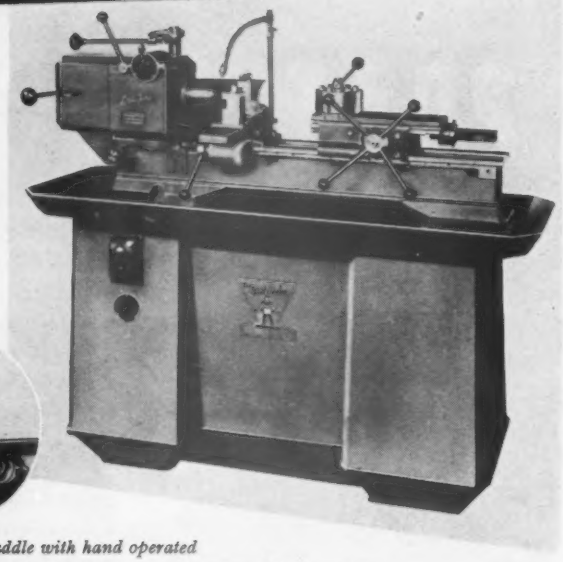

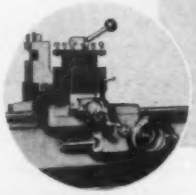

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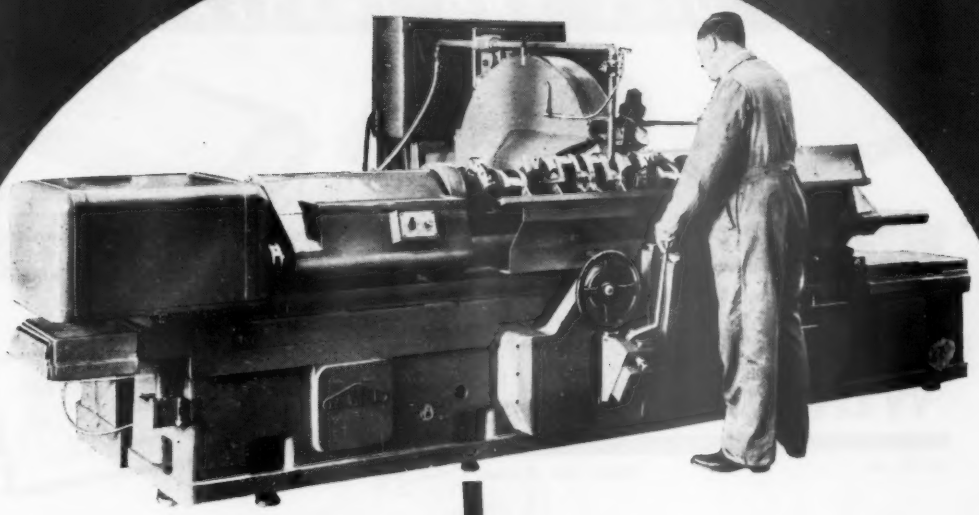

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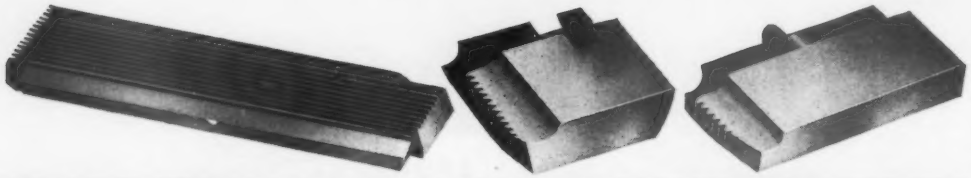

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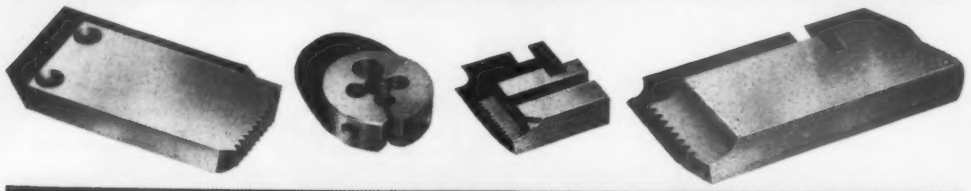

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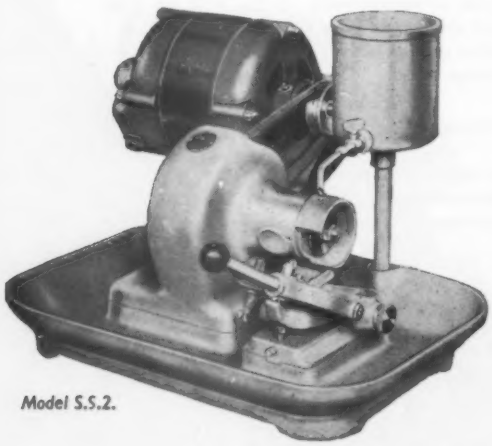

Model S.S.2.

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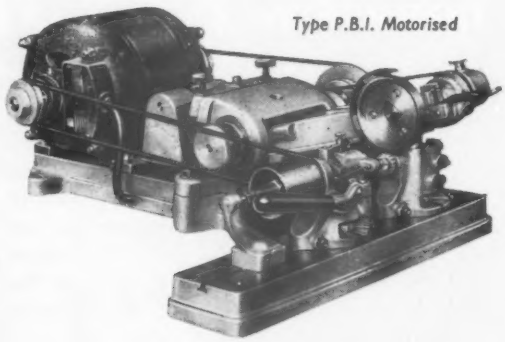
Type P.B.I. Motorised



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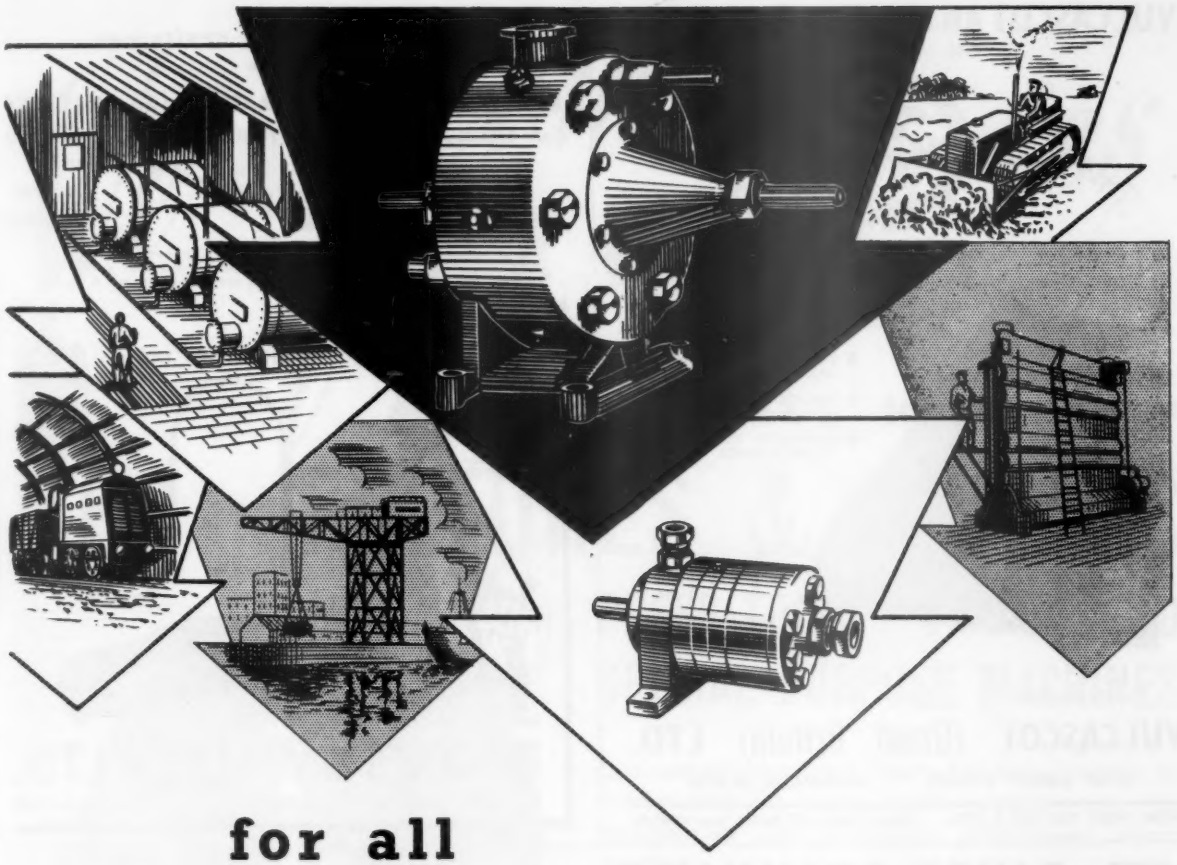

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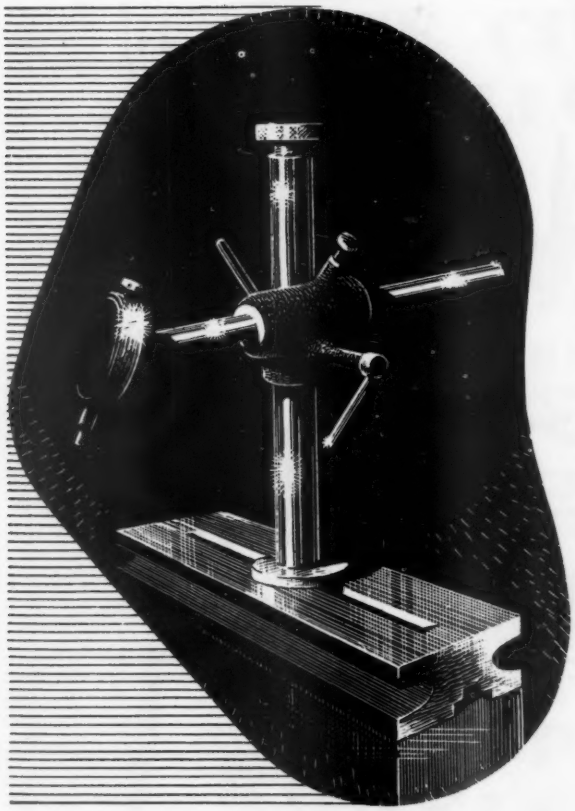

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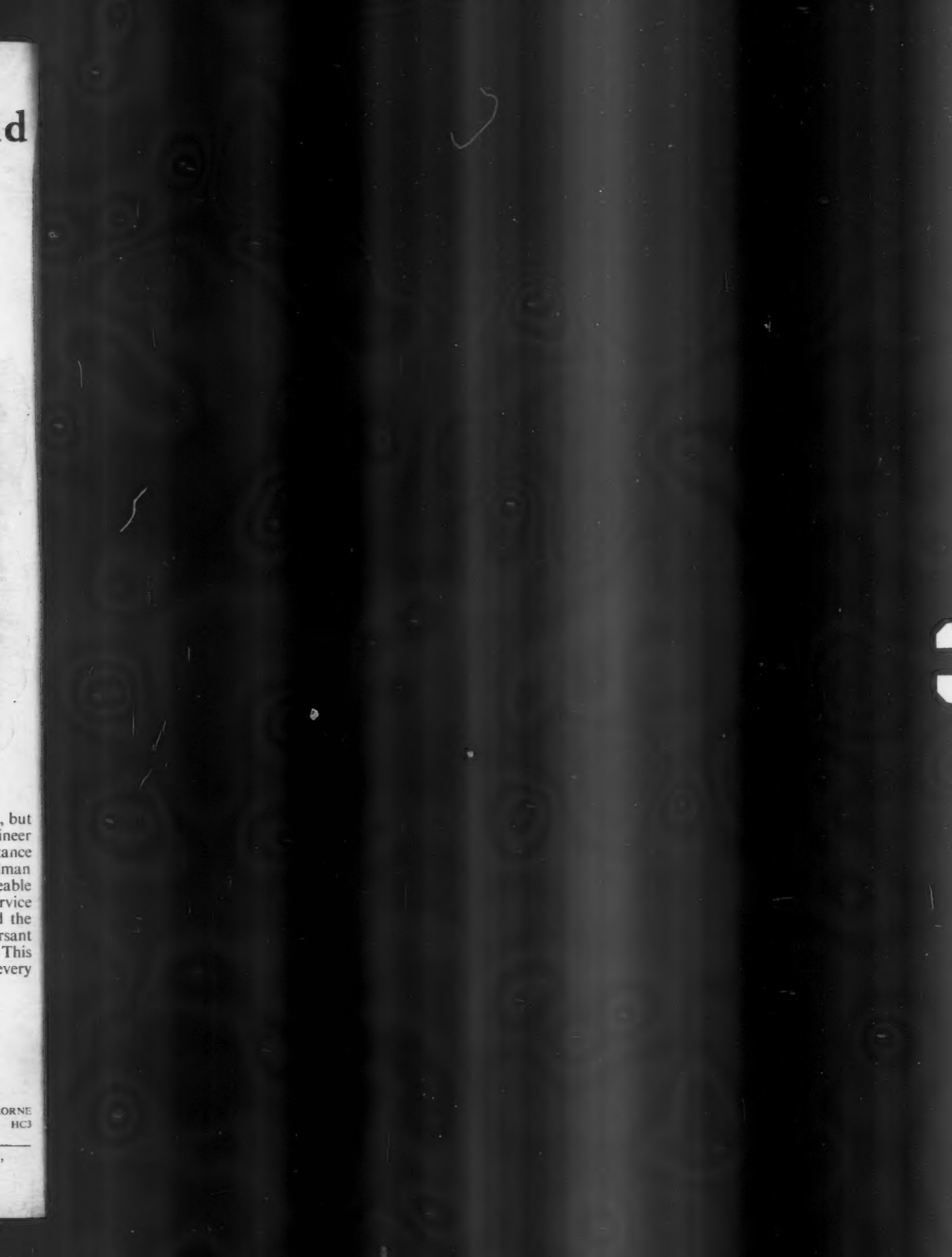
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